

FM 6-40

DEPARTMENT OF THE ARMY FIELD MANUAL

FIELD ARTILLERY CANNON GUNNERY

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FIELD ARTILLERY CANNON GUNNERY

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PART ONE

GENERAL

CHAPTER 1

INTRODUCTION

Section I. GENERAL

1-1. Purpose

This manual explains the field artillery cannon gunnery problem and presents a practical application of the science of ballistics and the procedures essential for the timely delivery of effective artillery fire. This manual is intended to be used only as a guide and cannot cover all situations; therefore, modifications may be made based on the knowledge of the gunnery supervisor and the state of training of the unit personnel. Any modifications which result in the loss of either speed or accuracy should be seriously questioned.

1-2. Scope

This manual encompasses all aspects of field artillery gunnery for cannons. The material presented herein is applicable without modification to both nuclear and nonnuclear warfare. The scope includes—

- a. Characteristics and capabilities of weapons and ammunition.
- b. Fundamentals of ballistics.
- c. Firing battery gunnery.
- d. Observer procedures.
- e. Fire direction.
- f. Miscellaneous gunnery information.

1-3. Changes or Corrections

Users of this manual are encouraged to submit recommended changes or comments to improve the manual. Comments should be keyed to the specific page, paragraph, and line of the text in which the change is recommended. Reasons should be provided for each comment to insure understanding and complete evaluation. Comments should be forwarded direct to U.S. Army Artillery and Missile School, ATTN: AKPSIAS-PL-FM, Fort Sill, Okla. 73503.

1-4. References

See the appendix for list of references.

1-5. The Field Artillery Gunnery Problem

Field artillery weapons normally are emplaced in defilade to conceal them from the enemy. For the vast majority of targets, placing pieces in defilade precludes sighting the weapon directly at the target (direct fire). Consequently, indirect fire must be employed to attack the targets. The gunnery problem is primarily the problem of indirect fire. The solution of this problem requires weapon and ammunition settings which, when applied to the piece and the ammunition, will cause the projectile to burst on, or at a proper height above, the target. The steps in the solution of the gunnery problem are—

- a. Location of the target and battery.
- b. Determination of chart data (direction, range, and vertical interval from weapons to target).
- c. Conversion of chart data to firing data.
- d. Application of firing data to the weapons.

1-6. Field Artillery Gunnery Team

The coordinated efforts of the field artillery gunnery team must be interconnected by an adequate communications system. The elements of the gunnery team are—

- a. *Observers.* The observers (to include all target acquisition devices) detect and report to the fire direction center the location of suitable targets, initiate calls for fire, and conduct an adjustment if necessary.
- b. *Fire Direction Center.* The fire direction center (FDC) evaluates the information received from the observers, determines firing data, and furnishes these data in the form of fire commands to the firing battery.

c. Firing Battery. The firing battery applies the firing data to the weapons and fires the weapons. The firing battery is the fire unit for field artillery.

1-7. Basic Principles of Employment of Field Artillery Firepower

a. Field artillery doctrine demands the timely and accurate delivery of fire to meet the requirements of supported units. All members of the artillery team must be continuously indoctrinated with a sense of urgency; they must strive to reduce by all possible measures the time required to execute an effective fire mission.

b. For artillery fire to be effective, it must be of suitable density and must hit the target at the proper time and with the appropriate projectile and fuze.

c. Good observation permits delivery of the most effective fire. Limited observation results in a greater expenditure of ammunition and less effective fire. Some type of observation is desirable for every target fired on in order to insure that fire is placed on the target. Observation of close-in battle areas is usually visual. When targets are hidden by terrain features or when greater distances or limited visibility are involved, observation may be either visual (air or flash) or electronic (radar or sound). When observation is available, corrections can be made to place artillery fire on targets by adjustment procedures; however, lack of observation must not preclude

firing on targets that can be located by other means.

d. Field artillery fires must be delivered by the most accurate means which time and the tactical situation permit. When possible, survey will be used to locate the gun (howitzer) position and targets accurately. Under some conditions, only a rapid estimate of the relative location of weapons and targets may be possible. However, survey of all installations should be as complete as time permits in order to achieve the most effective massed fires. Inaccurate fire wastes ammunition and reduces the confidence of supported troops in their artillery support.

e. The immediate objective is to deliver a mass of accurate and timely fire so that the maximum number of casualties are inflicted. The number of casualties inflicted in a specific target area can be increased in most instances by surprise fire. If surprise massed fires cannot be achieved, the time required to bring effective fire on the target should be reduced to the minimum.

f. The greatest demoralizing effect on the enemy can be achieved by delivering a maximum number of rounds from many pieces in the shortest possible time and without adjustment. Accurate massed fire with one round per weapon from six batteries will be much more effective than six rounds per weapon from one battery, provided that all rounds arrive on the target simultaneously.

g. Artillery units must be prepared to handle multiple fire missions when the situation so dictates.

Section II. CANNON ARTILLERY

1-8. General

a. Cannon artillery is classified according to caliber and maximum range capability as light, medium, heavy, and very heavy.

- (1) Light—120-mm and less.
- (2) Medium—Greater than 120-mm but not greater than 160-mm.
- (3) Heavy—Greater than 160-mm but not greater than 210-mm.
- (4) Very heavy—Greater than 210-mm.

b. Cannon artillery is also classified according to the method of organic transportation.

- (1) *Towed*—Cannons mounted on carriages

designed to be towed behind prime movers.

- (2) *Self-propelled*—Cannons permanently installed on full-track vehicles which provide motive power for the piece and from which the weapon is fired.

1-9. Characteristics and Capabilities

Some of the characteristics and capabilities of field artillery weapons and tank weapons used in an indirect fire role are listed in table 1-1.

Table 1-1. Characteristics and Capabilities of Artillery Weapons

(Located in back of manual)

Section III. AMMUNITION

1-10. General

A complete round of artillery ammunition contains all the components necessary to propel the projectile from the weapon and cause it to burst at the desired time. The components are the primer, propelling charge, projectile, and fuze. Depending on the manner in which the components are assembled, artillery ammunition is classified as fixed, semifixed, separate-loading, and separated. See TM 9-1300-203 for details on artillery ammunition. See table 1-2 for ammunition available for each cannon.

Table 1-2. Ammunition Chart
(Located in back of manual)

1-11. Primers

Primers are used to ignite the propelling charge. Percussion primers are ignited by a sharp blow with a firing pin. Electric primers are ignited by sending a small electric current through a resistor imbedded in an explosive. If the primer is not capable of igniting the propellant, an igniter charge is added to the propellant and placed between the primer and the propellant.

1-12. Propelling Charge

A propelling charge is a low-order explosive, which, when burned, generates pressure within the chamber and, thereby, furnishes the energy to propel the projectile. Propelling charges are packed loose in shell cases (fixed ammunition), in cloth bag increments (semifixed or separate-loading ammunition) or, in the case of the 4.2-inch mortar, in sheetlike bundles attached to a cartridge container. Greater flexibility in projectile range and angle of fall is provided by varying the number of increments to be fired, which varies the muzzle velocity.

1-13. Projectiles

A projectile is an object that is propelled from a weapon by an explosive propellant charge. All projectiles are of the same general shape in that they have cylindrical bodies and an ogival head.

a. High-Explosive Projectiles. High-explosive (HE) projectiles are hollow projectiles filled with either composition B or TNT. The terminal ballistics

and effects of these projectiles are discussed in chapter 2.

b. Base-Ejection Projectiles. Base-ejection projectiles are smoke, propaganda, illuminating, or selected ammunitions. The contents of the projectile are ejected from the base of the projectile through the action of the time fuze and expelling charge before the projectile reaches the point of impact.

c. Burster-Type Chemical Projectiles. Burster-type chemical projectiles include gas projectiles and smoke projectiles. The contents of the projectiles are expelled upon action of a burster projectile charge which runs through the long axis of the projectile.

d. High-Explosive, Antitank Projectiles. High-explosive, antitank (HEAT) projectiles are provided for the 105-mm howitzer for use against armored materiel. The projectile body is a thin-walled casing which contains a shaped high-explosive charge. The projectile has a ballistic cap of thin steel to provide better ballistic performance during flight.

e. High-Explosive, Plastic Projectiles. High-explosive, plastic (HEP) projectiles are used primarily against armored targets. The cartridge has one bag of propellant M6 for its propelling charge. The projectile body is a thin-walled casing containing composition A3 and is internally threaded at the base to receive a base detonating (BD) fuze. When the cartridge is fuzed with the M91 or M91A1 BD fuze, it is designated high-explosive plastic tracer (HEP-T) (the BD 91 series fuzes contain a tracer). When the cartridge is fuzed with the BD M62A1 fuze, which has no tracer, it is designated high-explosive plastic.

1-14. Fuzes

The proper fuze must be used to cause the projectile to function at the time and place desired. Fuzes are classified according to the method of functioning as time, impact, or proximity (variable time (VT)).

a. Time fuzes contain a graduated time element similar to the works in a clock that may be set, prior to firing, to a predetermined setting. After

the projectile has been fired, the time fuze functions as soon as the time corresponding to this setting has elapsed.

b. Impact fuzes function when they strike a solid object. Impact fuzes are further classified according to the delay of action after impact as superquick, nondelay, delay, and concrete pierc-

ing (CP). Concrete piercing is a special purpose impact fuze characterized with a hard nose, shield, and delay action for penetration.

c. Proximity (VT) fuzes function when they approach any object which will reflect with sufficient strength the signal radiated from the fuze.

Note. See table 1-2 for fuze interchangeability.

CHAPTER 2

FUNDAMENTALS OF FIELD ARTILLERY GUNNERY

Section I. ELEMENTS OF FIRING DATA

2-1. General

a. The data required to lay (point) an artillery cannon so that the projectile, when fired, will burst at the desired location are called firing data. These data are based on the direction, horizontal range, vertical interval, and meteorological conditions from the weapons to the target and on the desired pattern of bursts at the target.

b. The principal unit of angular measurement in field artillery is the mil. A mil is the angle subtended by an arc which is one sixty-four-hundredth of the circumference of a circle.

2-2 Direction

Direction is expressed as a horizontal angle measured from a fixed reference. The field artillery normally uses grid north (the direction of the north-south grid lines on a military map) for the fixed reference and measures the angle clockwise from grid north. When pieces are emplaced, they are laid for direction, and the direction in which they are laid is used as a basis for angular shifts to point the pieces at the target. The direction to the target may be computed, determined graphically, or estimated.

2-3. Range

Range is the horizontal distance from the gun to the target and is expressed in meters. Range may be computed, measured graphically, or estimated. The range achieved by a projectile is a function of the charge (muzzle velocity) and the vertical angle (elevation) to which the tube is raised. (For other factors affecting range, see para 2-9.)

2-4. Vertical Interval

Vertical interval is the difference in altitude between the battery or observation post and the target or point of burst. The altitudes are deter-

mined from maps, by surveys, or by a shift from a known point.

2-5. Distribution of Bursts

Distribution of bursts is the pattern of bursts in the target area. Normally, all pieces of a battery fire with the same deflection, fuze setting, and quadrant elevation. However, since targets may be of various shapes and sizes, it is sometimes desirable to adjust the pattern of bursts to the shape and size of the target.

a. In some cases, individual piece corrections for deflection, fuze setting, and/or quadrant elevation are computed and applied to obtain a specific pattern of bursts. These corrections are called special corrections.

b. The term "sheaf" is used to denote the lateral distribution of the bursts of two or more pieces fired together. The width of the sheaf is the lateral distance (perpendicular to the direction of fire) between the centers of the flank bursts. The front covered by any sheaf is the width of the sheaf plus the effective widths of one burst. A sheaf may be formed in any one of the following patterns:

- (1) *Parallel (normal) sheaf.* A parallel sheaf is one in which the trajectories of all pieces are parallel (fig. 2-1).
- (2) *Converged sheaf.* A converged sheaf is one in which the horizontal and vertical planes of the trajectories intersect at the target (fig. 2-2).
- (3) *Open sheaf.* An open sheaf is one in which the lateral distance between the center of two adjacent bursts is equal to the maximum effective width of one burst (table 2-1 and fig. 2-3).
- (4) *Special sheaf.* A special sheaf is any sheaf other than one of those described in (1) through (3) above.

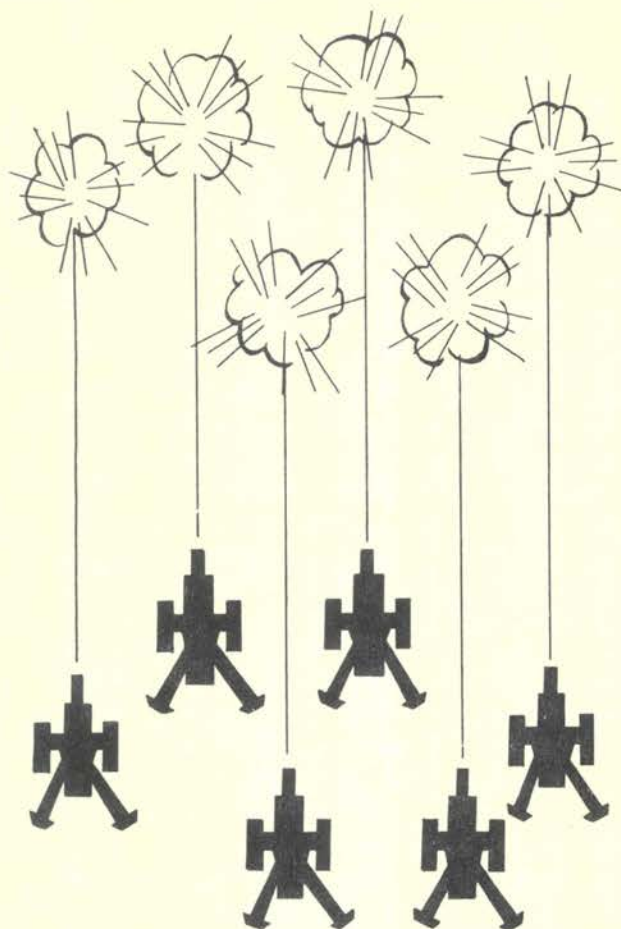


Figure 2-1. Parallel (normal) sheaf.

Table 2-1. Open Sheafs

Caliber	Width (in meters) of open sheaf			Front (in meters) covered by an open sheaf		
	2-piece battery	4-piece battery	6-piece battery	2-piece battery	4-piece battery	6-piece battery
105-mm and 4.2-inch mortar-----	30	90	150	60	120	*180
155-mm-----	50	150	250	100	200	*300
175-mm-----	95	285	----	190	380	----
8-inch-----	80	240	----	160	320	----

*For fire planning purposes, final protective fires by a 6-piece howitzer battery normally will be—

- (1) 200 meters in width for 105-mm.
- (2) 300 meters in width for 155-mm.

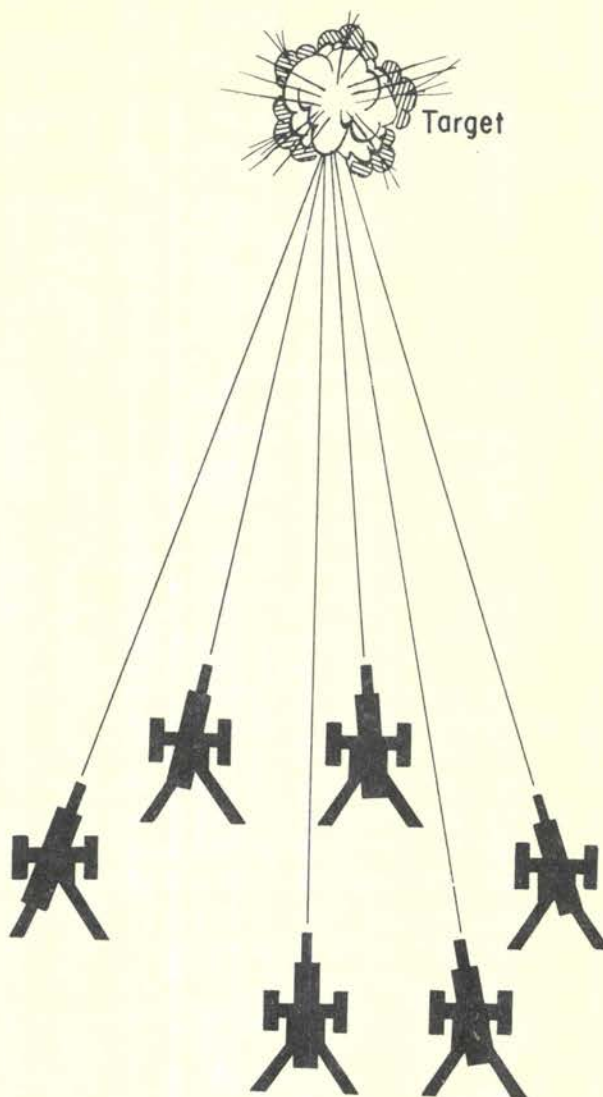


Figure 2-2. Converged sheaf.

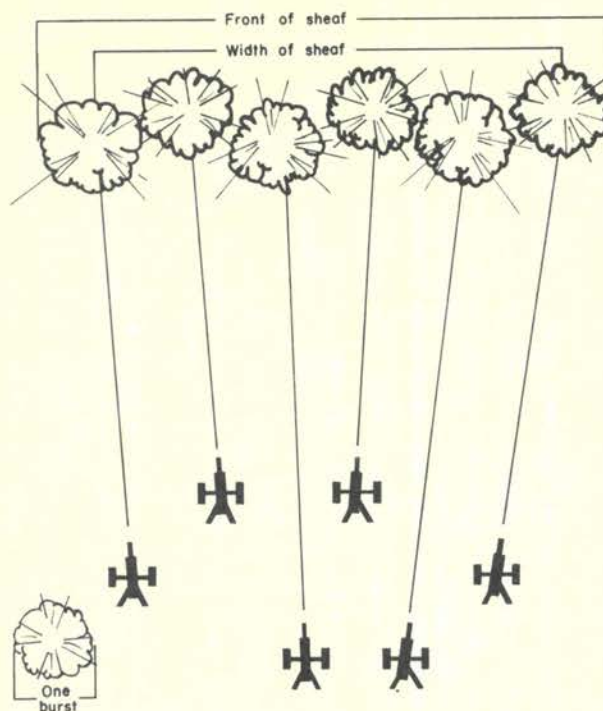


Figure 2-3. Open sheaf

Section II. INTERIOR BALLISTICS

2-6. General

Interior ballistics is the science which deals with the factors affecting the motion of projectiles before they leave the muzzle of the piece. The total effect of all interior ballistic factors determines the velocity with which the projectile leaves the muzzle. This velocity is called the muzzle velocity and is expressed in feet or meters per second. Actual measurements of the muzzle velocity of a series of rounds, corrected for nonstandard conditions, depict the performance of a certain weapon-ammunition combination. The result of these measurements can be compared with the standard velocities listed in the firing table for the charge fired in order to obtain the variation from standard. Application of corrections to compensate for nonstandard muzzle velocity is one of the most important elements in preparation of accurate firing data.

2-7. Nature of Propellants and Projectile Movement

a. A propellant is a low-order explosive which

burns rather than detonates. In artillery cannons using separate-loading ammunition, the propellant is burned in a chamber consisting of the powder chamber and the base of the projectile; in cannons using fixed and semifixed ammunition, the propellant is burned in a chamber consisting of the shell case and the base of the projectile. When the gases generated by the burning propellant develop pressure sufficient to overcome initial bore resistance, the projectile begins to move.

b. The gas pressure builds up quickly to a peak and gradually subsides shortly after the projectile begins to move. The peak pressure, together with the travel of the projectile in the bore (pressure-travel curve), determines the speed at which the projectile leaves the tube (fig. 2-4).

c. Various factors which affect the velocity performance of a weapon-ammunition combination are given in (1) through (5) below.

- (1) An increase in the rate of burning of a propellant increases resultant gas pressure.
- (2) An increase in the size of the powder chamber without a corresponding in-

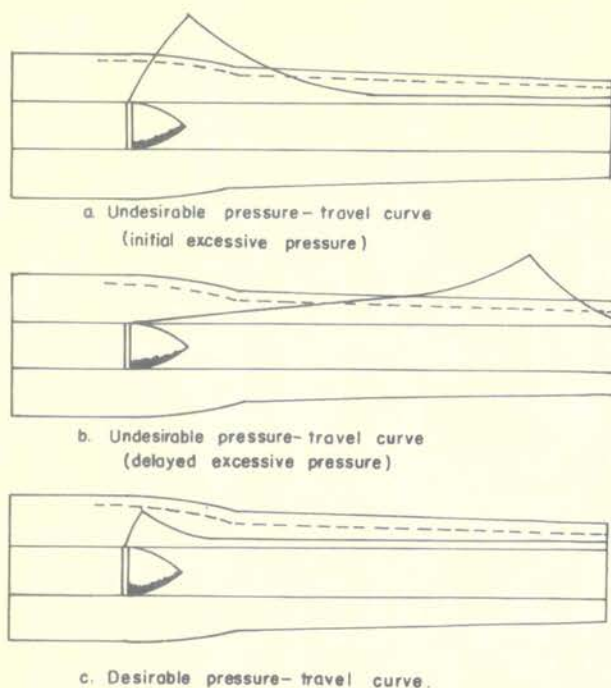


Figure 2-4. Pressure-travel curves

crease in the amount of propellant decreases gas pressure.

- (3) Gas escaping around the projectile in the tube decreases pressure.
- (4) An increase in bore resistance to projectile movement before peak pressure further increases pressure.
- (5) An increase in bore resistance at any time has a dragging effect on the projectile and decreases velocity. Temporary variations in bore resistance are caused by extraneous deposits in tubes and on projectiles and by differences in heat between the inner and outer surfaces of the tube.

2-8. Standard Muzzle Velocity

a. Appropriate firing tables give the standard value of muzzle velocity for each charge. These standard values are based on an assumed standard tube. The standard values are points of departure, not absolute standards, since they cannot be reproduced in a given instance; that is, a specific weapon-ammunition combination cannot be selected with the knowledge that it will result in a standard muzzle velocity when fired.

b. Charge velocities are established indirectly

by the military characteristics of a weapon. Cannons capable of high-angle fire (mortars and howitzers) require a greater choice in number of charges than do cannons primarily capable of low-angle fire (guns). This greater choice is needed in order to achieve range overlap between charges in high-angle fire and the desired range-trajectory combination in low-angle fire. Other factors considered in establishing charge velocities are the maximum range specified for the weapon and the maximum elevation and charge (with resulting maximum pressure) which the weapon can accommodate.

c. Manufacturing specifications for ammunition include the required velocity performance within certain tolerances. The ammunition lots are subjected to firing tests which include measuring the performance of the lots tested against the concurrent performance of a control or reference lot. Both the control lot and the lot being tested are fired through the same tube, assuming that whatever the characteristics of that tube, the performance of both lots is influenced identically. The foregoing assumptions, although accurate enough for firing tests, are not entirely correct and allow a certain amount of error in propellant assessment procedures. (Assessment procedures include correcting charge weights for the tested lot to match the velocity developed by the control lot during the test.) Therefore, a wide variation in the performance of ammunition under field conditions can be expected even though quality control over manufacture is exercised. Also, if a cannon develops a muzzle velocity 3.0 meters per second faster (or slower) than another weapon with the same charge lot, it will not necessarily do the same with any other charge of any other lot. However, weapon-ammunition performance is not so unstable that the prediction of future performance based on past results should not be attempted.

2-9. Factors Causing Nonstandard Muzzle Velocity

In gunnery techniques, nonstandard velocity is expressed as a variation (plus or minus so many feet or meters per second) from an accepted standard. Round-to-round corrections for dispersion cannot be made. In the discussion in *a* through *c* below, each factor is treated as a single entity assuming no influence from related factors.

a. Velocity Trends. Not all rounds of a series fired from the same weapon using the same ammunition lot will develop the same muzzle velocity. The variations in muzzle velocity follow a normal probability distribution about the average muzzle velocity. This phenomenon is called velocity dispersion. Under most conditions, the first few rounds follow a somewhat regular pattern rather than the random pattern associated with normal dispersion. This phenomenon is called velocity trend. The magnitude and extent (number of rounds) of velocity trends vary with the cannon, charge, and tube condition at round 1 of the series, and firings preceding the series. Velocity trends cannot be accurately predicted; therefore, any attempt to correct for the effect of a velocity trend is impractical. Characteristic velocity trends for some weapons, however, can be detected. A comparison of velocity trends for a 105-mm howitzer when a series of rounds is fired starting with an oily tube, a tube cleaned with rags only, and a tube cleaned with soap and water is shown in figure 2-5. Generally, the magnitude and duration of velocity trends can be minimized when firing

is started with a tube which is clean and completely free of oil.

b. Ammunition Lots. Each lot of ammunition has its own mean performance level when related to a common tube. Although the round-to-round probable error within each lot is about the same, the mean velocity developed by one lot may be much higher or lower than that of another lot. With separate-loading ammunition, both the propellant and the projectile lots must be identified. Variations in the projectile, e.g., the diameter and hardness of the rotating band, affect muzzle velocity. (Projectile variations have a much more apparent effect on exterior ballistics.)

c. Tolerances in New Weapons. All new cannons of a given caliber and model will not necessarily develop the same muzzle velocity. In a new tube, the predominant factors are variations in the powder chamber and the interior dimensions of the bore. If a battalion armed with new cannons fired all of them with a common lot of ammunition, a velocity spread of 3 or 4 meters per second between the cannon with the highest muzzle velocity and the cannon with the lowest muzzle velocity

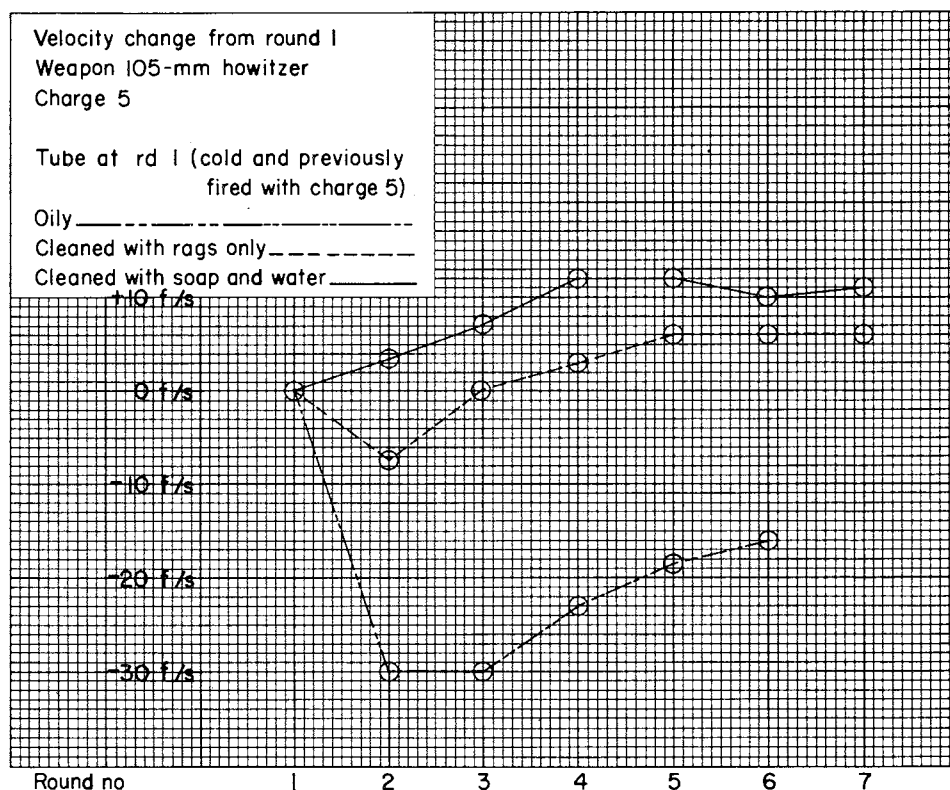


Figure 2-5. Velocity trends

would not be unusual. Therefore, cannons must be calibrated even though they are new.

d. Wear of Tube. Continued firing of a cannon wears away portions of the bore by the action of heated gases, chemical action, and movement of the projectile. These erosive actions are more pronounced when higher charges are being fired. Increased tube wear tends to decrease muzzle velocity by allowing the projectile to be seated farther forward in the tube and thereby allowing more room for expanding gases, by allowing the expanding gases to escape past the rotating band, and by decreasing resistance to initial projectile movement which lessens pressure buildup. Although normal wear cannot be prevented, it can be minimized by careful selection of the charge and proper cleaning of both weapon and ammunition. Calibration data must be kept current, since losses in velocity do not uniformly follow an increase in measured wear.

e. Nonuniform Ramming. Although a weak ram would decrease the volume of the propellant chamber and thereby theoretically increase the push given the projectile (the pressure of a gas varies inversely with the volume), this is only a partial effect. Improper seating (cocking) of the projectile, as a result of improper ramming, allows some of the expanding gases to escape without doing any work, and a lower velocity results. The combined effect of escaping gases and a smaller propellant chamber is hard to predict. Weak, nonuniform ramming produces an increase in the dispersion pattern. Hard, uniform ramming is required for all rounds. When fixed and semifixed ammunition are being fired, the principles of varying volume propellant chamber and escape of gases still apply, especially in worn tubes. Since the obturation of the cartridge case serves as the gas check to the rear in fixed and semifixed ammunition, proper handling and seating of the case is important in reducing escape of gases.

f. Rotating Bands. Ideal rotating bands allow proper seating, provide obturation, create proper resistance to initial projectile movement to allow uniform pressure buildup, and also provide a minimum dragging effect on the projectile once motion has started. Dirt or burs on the rotating band cause improper seating, which increases tube wear and contributes to velocity dispersion. If ex-

cessively worn, the lands may not sufficiently engage the rotating bands to impart proper spin to the projectile. Insufficient spin reduces projectile stability in flight and can result in dangerously short, erratic rounds. When erratic rounds occur or excessive tube wear is noted, ordnance ballistic and technical service teams should be called upon to determine the serviceability of each tube by wear measurements and other checks.

g. Propellant Temperature. Any combustible material burns more rapidly when it is heated prior to ignition. When a propellant burns more rapidly, the resultant pressure on the projectile is greater and muzzle velocity is increased. The firing tables show the magnitude of this change. Appropriate corrections to firing data can be computed; however, such corrections are valid only as they reflect the true propellant temperature. The temperature of propellants in sealed packing cases remains fairly uniform, though not necessarily standard (70° F.). Once the propellant is unpacked, its temperature tends to approach the prevailing air temperature. The time and type of exposure to weather result in propellant temperature variations between rounds as well as mean propellant temperature variations between gun sections. It is not practical to measure propellant temperature and apply corrections for each round fired by each cannon. Positive action must be taken to maintain uniform propellant temperatures; failure to do so results in erratic firing. The effect of a sudden change in propellant temperature can invalidate even the most recent registration corrections.

- (1) Ready ammunition should be kept off the ground; should be protected from dirt, moisture, and the direct rays of the sun; and should have an airspace between the ammunition and protective covering. This procedure allows propellants to approach atmospheric temperature at a uniform rate.
- (2) A sufficient number of rounds should be unpacked in advance so that it is not necessary during a mission to mix freshly unpacked ammunition with ammunition which has been opened for some time.
- (3) Rounds should be fired in the same order as they are unpacked.
- (4) Propellant temperatures of ready am-

munition should be taken at random points in the ammunition stack and checked periodically at intervals dependent on the changes in ambient temperature. The rounds so checked should not be removed from the rest of the ammunition but should be measured in place to get a true mean temperature. The thermometer should penetrate the propellant and must not touch any metal.

- (5) Propellants should be exposed to a heated powder chamber for the shortest possible time.

h. Moisture Content of Propellant. Handling and storage can cause changes in the moisture content of the propellant, which will affect the velocity. The moisture content of the propellant cannot be measured or corrected for; therefore, ammunition must be provided maximum protection from the elements.

i. Position of Propellant in Chamber. In fixed and semifixed ammunition, the propellant has a relatively fixed position with respect to the chamber—the chamber being, in effect, the cartridge case. The position of separate-loading propellants, however, depends on how the cannoneer inserts the charge. The base of the propellant bag should be flush against the obturator spindle at the instant of firing of the primer in order to insure ignition of the propellant. Variations in the diameters of the bags also affect propellant performance. An increase in the bag diameter for the same amount of propellant tends to increase the rate of burning and the resultant velocity. Loose tie straps or wrappings have the effect of increasing the bag diameter from the original diameter; therefore, cannoneers should check wrappings for tightness even when the full charge is being used.

j. Weight of Projectile. The weight of like projectiles varies within certain weight zones. The appropriate weight zone is stenciled on the projectile. Some projectiles are not grouped in weight zones but are marked with the weight in pounds. A heavier than standard projectile is harder to push throughout the length of the tube and a decreased velocity results, whereas a lighter projectile is easier to push throughout the length of the tube and a higher velocity results. (Weight of projectile is also a factor in exterior ballistics.)

k. Coppering. Coppering is the deposit of a

thin film of copper on the bore. Coppering occurs in the tube when the velocity is high enough to develop sufficient friction to remove the outside surface of the rotating band. Coppering is more pronounced in high-velocity weapons and with higher charges. The amount of copper deposited varies with the velocity. Firing with lower charges will reduce coppering. Slight coppering, such as that resulting from firing a few rounds at the higher charges with a howitzer, tends to increase muzzle velocity; excessive coppering causes erratic velocity performance by varying the resistance of the bore to projectile movement. The removal of excessive copper is an ordnance function.

l. Propellant Residues. Residues from the burned propellant and certain chemical agents mixed with the expanding gases are deposited on the bore surface in a manner similar to coppering. Unless the tube is properly cleaned and cared for, these residues aggravate subsequent tube wear by causing pitting and augmenting the abrasive action of the projectile.

m. Tube Conditioning. The temperature of the tube has a direct bearing on the developed velocity. For example, a cold tube offers a different resistance to projectile movement than a warm tube. A cold tube is less susceptible to coppering even at high velocities. The results of the warmup process can appear as a trend of increasing or decreasing velocities, depending on the weapon, charge, oiliness of the tube, and the degree of coppering.

- (1) Ammunition is tested in tubes which have been thoroughly conditioned to a desired velocity level by firing several warmup rounds. Tubes which are not conditioned will not allow propellants to perform as they did when tested. Also, the round-to-round variation is much greater during the conditioning period.
- (2) If the velocity for a certain weapon-ammunition combination is at its true level only after sustained fire at a specified rate of fire, either increases in the rate of fire or lulls in firing can upset this true level. A change of charge can have a noticeable effect on velocity level. For example, if a 105-mm howitzer is conditioned (brought to the true velocity level) with charge 7 (MV 465), it will be slightly overconditioned for charge 4

(MV 262). Also, if firing is performed immediately with the lower charge, a tendency toward higher than normal velocities will be experienced on the first one or two rounds. Going from a lower to a higher charge also introduces the possibility that the first one or two rounds will have a lower than normal velocity. It is doubtful whether firing with the lowest charge only can truly condition a tube to normal operating velocity levels, since the warming up process is so slow at low velocities. For example, for the 105-mm howitzer, firing started with charge 3 has resulted in an average variation from standard velocity of 3.0 to 4.6 meters per second less than when firing with charge 3 was preceded by firing with charge 7. The tactical situation seldom allows the firing of conditioning rounds. However, the lack of tube conditioning is a factor that the S3 must consider in attacking targets without adjustment or in firing close to friendly troops. Likewise, possible velocity trends should be considered in mean-point-of-impact and high-burst registrations and in calibration firing.

- (3) In general, tube conditioning involves two different effects. One effect is that of heating the tube until the temperature differential from inner to outer surfaces is stabilized for the rate of fire and charge to be used. The other effect is that of bringing the bore resistance from coppering and propellant residues to a stabilized condition at the rate of fire and charge to be used. The first few rounds show the greatest difference from the intended level. However, these are the very rounds that determine the accuracy of fire-for-effect missions. It is not possible at the present time to include corrections for these trends in firing data. It may never prove feasible to include such corrections for most cannons because of the many variations between the conditioned and the unconditioned tube.
- (4) When calibration involves more than one charge, the higher charge is fired first, since conditioning for the lower charge

occurs with fewer rounds if the first rounds are fired at the highest velocity. Two to four rounds should be sufficient when the highest charge is fired; however, the observed results are the only valid criteria. Calibrations conducted with the lower charges of the 105-mm, 155-mm, and 8-inch howitzers, and 175-mm gun, without prior conditioning with higher charges will require more rounds to reach a conditioned tube status. If conditioning has been accomplished with one charge and a change to another charge is required, at least one conditioning round should be fired with the new charge.

- (5) Guns are more sensitive to changes in the rate of fire than howitzers. The accuracy of preparation fire is adversely affected by rapid firing followed by intermittent lulls of varying length.
- (6) The previous conditioning of any weapon is affected by lulls in firing and ambient air temperature. If the lull is no longer than 1 hour, normally the firing of one round will bring the cannon to the previous velocity level. If the tube is cleaned during relatively short lulls, erratic velocities may be experienced for the first few rounds after cleaning. If the cleaning is accomplished during long lulls, the normal velocity trends previously described may be expected. The conditioning of the tube is destroyed more quickly during lulls in firing in extremely cold temperature than in warm temperature. During cold weather, the firing of more rounds may be necessary to bring the cannon to the proper velocity level.
- (7) Oil or moisture in the tube or on the rotating band tends to increase velocity of the particular round by causing a better initial gas seal and reducing projectile friction on the bore surface. The oily tube condition usually exists concurrently with the cold tube condition. Hence the high velocities induced by oil combining with the erratic velocities characteristic of a cold tube complicate normal velocity trends. When these factors are coupled with coppering and powder residues, it

is hard to predict corrections for velocity trends. Moisture on the projectile normally affects only that particular round. Generally, firing with a cold, dry tube is preferable to firing with a cold, oily tube, and projectiles should be dry regardless of tube conditions. Figure 2-5 illustrates velocity trends measured under the conditions stated. The graph in figure 2-5 is not to be construed as the basis for determining corrections to firing data. It is merely an example of observed results which most nearly portrays the cannon and condition specified after repeated observations.

n. Determination of Muzzle Velocity. The accuracy of artillery fires could be improved if actual muzzle velocities developed by each tube at time of firing were known. Obtaining such data is not feasible at the present time. Therefore, knowledge of past performance of a weapon-ammunition combination must be relied on for the data needed and velocity performance predicted on this basis. The velocity level of each weapon must be determined at every opportunity. Methods used to determine comparative and absolute velocity performance of a group of weapons are discussed in chapter 23. Aspects of calibration are discussed in detail in paragraphs 2-10 through 2-27.

o. Charge-to-Charge Propellant Performance. One of the major problems in gunnery is how to best extend the data developed from firing one charge to all other charges. From the viewpoint of muzzle velocities only, there is no basis in available data to state that charge-to-charge performance follows a convenient ratio. Since propellants are manufactured to

provide standard performance within any given charge, a variation from standard in one charge does not fix a similar or proportional variation in another charge. The velocity level for a charge of a particular lot can be determined only by firing. Once the velocity level is determined, its relative level, with respect to other charges of that lot similarly determined, remains fairly stable. The velocity level developed at a given time by a certain charge is influenced by the state of the tube conditioning. This is particularly noticeable in the lower charges.

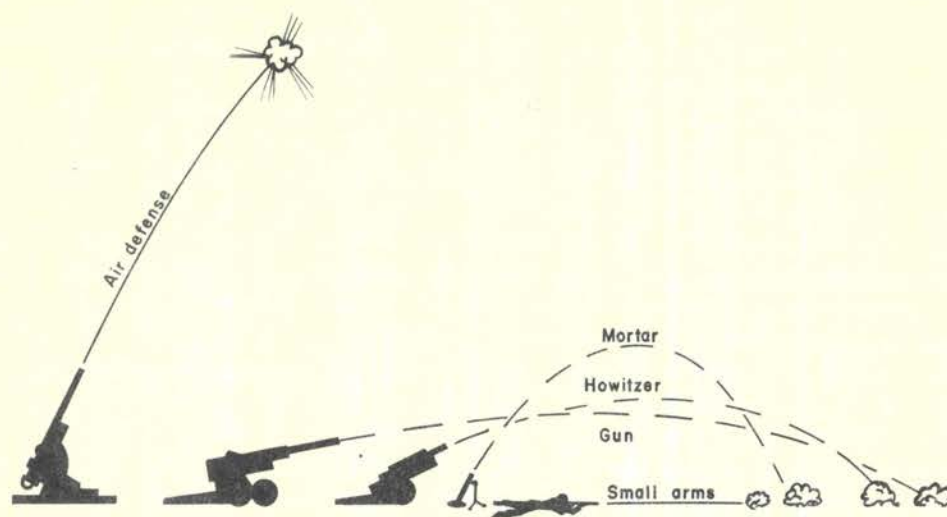
★*p. Projectile Temperature.* The effect of temperature on the projectile casing and the filler may cause a warping of the projectile casing including the fuze cavity (specifically the threads in the cavity). This effect may then result in improper seating of the projectile in the tube. When this occurs, the sealing action of the rotating band may not be complete and gases may escape upon combustion. The result will be a loss in developed muzzle velocity and a subsequent decrease in range. When the fuze well does not permit the proper seating of the VT fuze, either fuze quick or time should be fired with that projectile, or the projectile should be rejected. Improper seating of the fuze may cause it to activate prematurely. Since there is no method of detecting the effect of temperature on the projectile casing with regard to proper seating, positive action must be taken to prevent sudden changes or varying changes in the temperature of the projectile. Those procedures that apply to the storage of propellant are also applicable to the projectile.

Section III. EXTERIOR BALLISTICS

2-10. General

a. Exterior ballistics is the science which deals with the factors affecting the motion of a projectile after it leaves the muzzle of a piece, at that instant, the total effect of interior ballistics in terms of developed muzzle velocity and spin have been imparted to the projectile. Were it not for gravity and the atmosphere, the projectile would continue indefinitely at constant velocity along a prolongation of the tube.

b. Gravity causes the projectile to return to the surface of the earth. If the projectile were fired in a vacuum, the path, or trajectory, would be simple to trace. All projectiles, regardless of size, shape, or weight, would follow same range for a given muzzle velocity and paths of the same shape and would achieve the tube elevation. However, if the projectile were fired in the atmosphere, the path, or trajectory, becomes a complex curve. There are two reasons for this. First, projectiles of different



★Figure 2-6. Typical trajectories.

sizes or weights respond differently to identical atmospheric conditions. Second, a standard atmosphere can be defined, but it is seldom experienced. The combinations and permutations of the variables affecting the atmosphere (and, thus, the path of a projectile) are great in number. A given elevation and muzzle velocity can result in a wide variety of trajectories, depending on the combined properties of both the projectile and the atmosphere.

c. Paragraphs 2-11 through 2-27 picture the trajectory, first, in a vacuum and, second, in the atmosphere and include a discussion of the projectile and the atmosphere and the interrelation of the two.

2-11. The Trajectory

The trajectory is the curve traced by the center of gravity of the projectile in its flight from the muzzle of the weapon to the point of impact or point of burst (fig. 2-6).

2-12. Elements of the Trajectory

The elements of the trajectory are classified in three groups—intrinsic elements, initial elements, and terminal elements. Intrinsic elements are those which are characteristic of a trajectory by its very nature. Initial elements

are those which are characteristic at the point of impact or point of burst.

2-13. Intrinsic Elements

The intrinsic elements of the trajectory (fig. 2-7) are discussed in *a* through *g* below.

a. *Origin*. The location of the center of gravity of the projectile when it leaves the muzzle of the piece is designated the origin of the trajectory. However, because the magnitude and the direction of jump and therefore the line of departure (para 2-14b and c) cannot be predetermined, the term "origin" will be used for the remaining definitions relating to the elements of the trajectory to designate the center of the muzzle when the piece has been laid.

b. *Ascending Branch*. The ascending branch is that portion of the trajectory traced while the projectile is rising from the origin.

c. *Descending Branch*. The descending branch is that portion of the trajectory traced while the projectile is falling.

d. *Summit*. The summit is the highest point of the trajectory. It is the end of the ascending branch and the beginning of the descending branch.

e. *Maximum Ordinate*. The maximum ordinate is the difference in altitude between the origin and the summit.

f. Level Point. The level point is the point on the descending branch of the trajectory which is at the same altitude as the origin.

g. Base of Trajectory. The base of the trajectory is the straight line from the origin to the level point.

2-14. Initial Elements

The initial elements of the trajectory (fig. 2-8) are discussed in *a* through *j* below.

a. Line of Elevation. When the piece is laid, the line of elevation is the axis of the tube extended.

b. Line of Departure. The line of departure is a line tangent to the trajectory at the instant the projectile leaves the tube.

c. Jump. Jump is the displacement of the line of departure from the line of elevation

that exists at the instant the projectile leaves the tube. Jump is caused by the shock of firing during the interval from the ignition of the propelling charge to the departure of the projectile from the tube.

d. Angle of Site. The angle of site is the smaller angle in the vertical plane from the base of the trajectory to the straight line joining the origin and the target. The angle of site is plus when the target is above the base of the trajectory and minus when the target is below the base of the trajectory. The angle of site compensates for the vertical interval (para 2-4).

e. Complementary Angle of Site. The complementary angle of site is an angle which is algebraically added to the angle of site to compensate for the nonrigidity of the trajectory. The trajec-

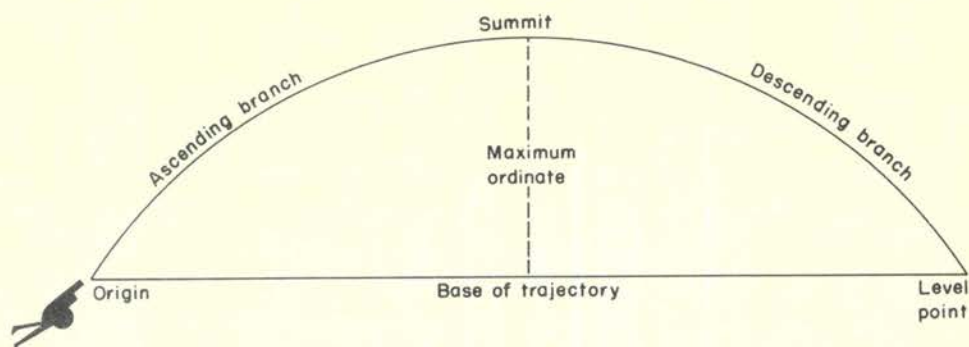


Figure 2-7. Intrinsic elements of the trajectory

tory may be rotated vertically about the origin an amount equal to small angles of site without significantly affecting its shape. When large angles of site or the longer ranges for any one charge are involved, significant error is introduced because the shape of the trajectory changes. The value and sign of the complementary angle of site depend on the angle of site, the range, the shape of the trajectory (low- or high-angle fire), and the muzzle velocity. The complementary angle of site (comp site) for ± 1 mil angle of site (comp site factor) is listed in the firing tables.

f. Site. Site is the algebraic sum of the angle of site plus the complementary angle of site.

g. Complementary Range. Complementary range is the range correction equivalent to the complementary angle of site. Complementary range can be determined from the firing tables.

h. Line of Site. The line of site is the straight line from the origin to the target which together with the base of the trajectory represents the angle called site.

i. Angle of Elevation. The angle of elevation is the smaller angle at the origin in a vertical plane from the line of site to the line of elevation.

j. Quadrant Elevation. The quadrant elevation is the smaller angle at the origin in a vertical plane

from the base of the trajectory to the line of elevation. Quadrant elevation is the algebraic sum of site plus the angle of elevation. Quadrant elevation can also be computed by algebraically adding the angle of site to the angle of elevation corresponding to range plus complementary range. The two methods of computing quadrant elevation, one using the complementary angle of site and the other using complementary range, both compensate for the nonrigidity of the trajectory. Complementary range may be used when the firing data are being determined from the firing table; complementary angle of site is used when site is being determined with graphical site table.

2-15. Terminal Elements

The terminal elements of the trajectory (fig. 2-9) are discussed in *a* through *e* below.

a. Point of Impact. The point of impact is the point where the projectile first strikes in the target area. (*The point of burst* is the point at which a projectile bursts in the air.)

b. Line of Fall. The line of fall is the line tangent to the trajectory at the level point.

c. Angle of Fall. The angle of fall is the vertical angle, at the level point, between the line of fall and the base of the trajectory.

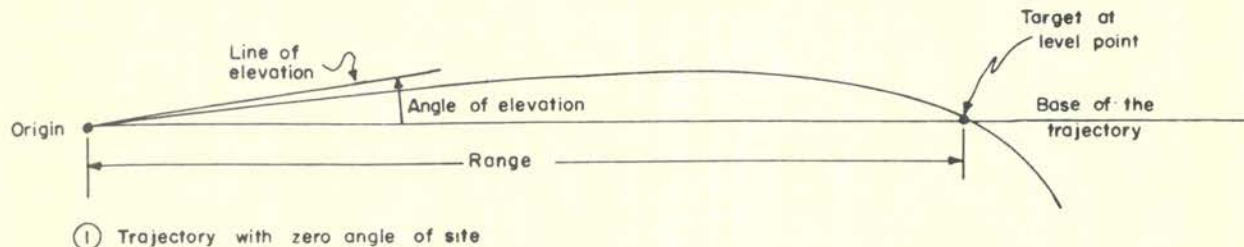
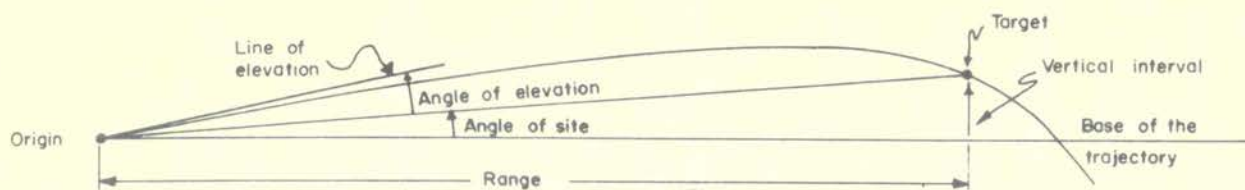
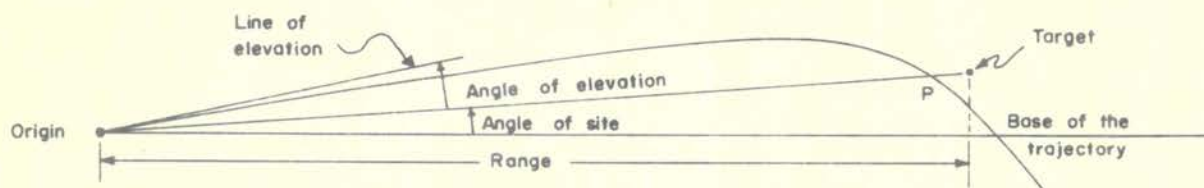


Figure 2-8. Initial elements of the trajectory



② Hypothetical (rigid) trajectory



③ Actual (nonrigid) trajectory

Figure 2-8—Continued

d. Line of Impact. The line of impact is a line tangent to the trajectory at the point of impact.

e. Angle of Impact. The angle of impact is the acute angle, at the point of impact, between the line of impact and a plane tangent to the surface at the point of impact. This term should not be confused with the term "angle of fall."

2-16. The Trajectory in a Vacuum

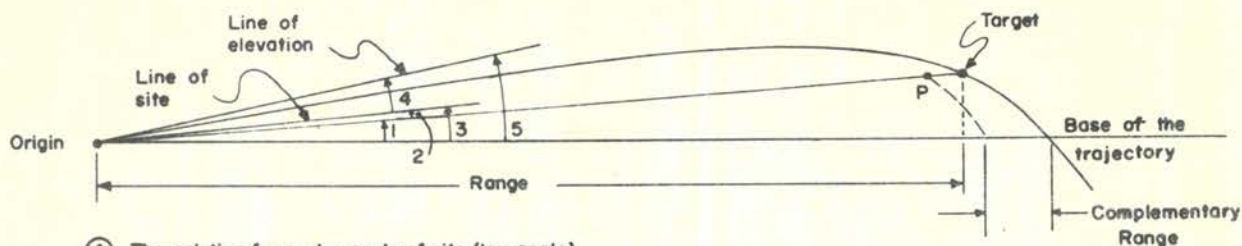
a. The factors which must be known to construct a firing table for firing in a vacuum are the angle of departure, the muzzle velocity, and the acceleration due to the force of gravity. The initial velocity imparted to a projectile consists of two components—a horizontal velocity and a vertical velocity.

b. The relative magnitudes of horizontal and vertical velocity components vary with the angle of elevation. For example, if the elevation were zero, the initial velocity imparted to the projectile would be horizontal; there would be no vertical component. If the elevation were 1,600 mils (dis-

regarding the effect of rotation of the earth), the initial velocity imparted to the projectile would be vertical; there would be no horizontal component.

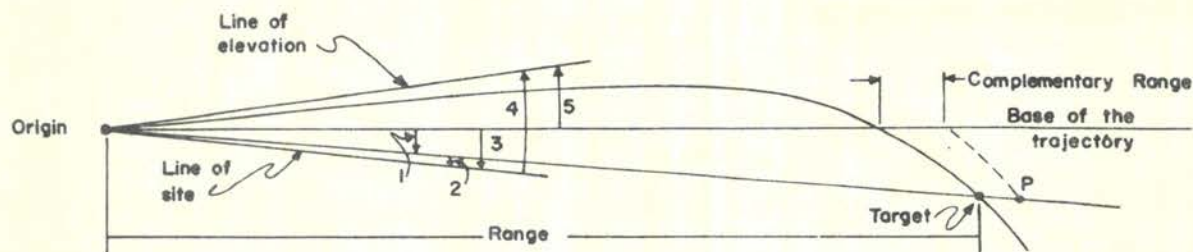
c. Gravity causes a projectile in flight to fall to the earth. Because of gravity, the height of the projectile at any instant is less than it would be if no such force were acting on it. In a vacuum, the vertical velocity decreases from the initial velocity to 0 on the ascending branch of the trajectory and increases from 0 to the initial velocity on the descending branch. Zero vertical velocity occurs at the trajectory summit. For every vertical velocity value upward on the ascending branch there is an equal vertical velocity value downward equidistant from the summit on the descending branch. Since there is no resistance to the forward motion of the projectile in a vacuum, the horizontal velocity component is a constant. The acceleration due to the force of gravity (9.8 meters per second²) affects only vertical velocity.

d. In a vacuum, the form of the trajectory would be determined entirely by the elevation of



④ The solution for a plus angle of site (low angle)

- 1: Angle of site
- 2: Complementary angle of site
- 3: Site
- 4: Angle of elevation
- 5: Quadrant elevation



⑤ The solution for a minus angle of site (low angle)

- 1: Angle of site
- 2: Complementary angle of site
- 3: Site
- 4: Angle of elevation
- 5: Quadrant elevation

Figure 2-8—Continued

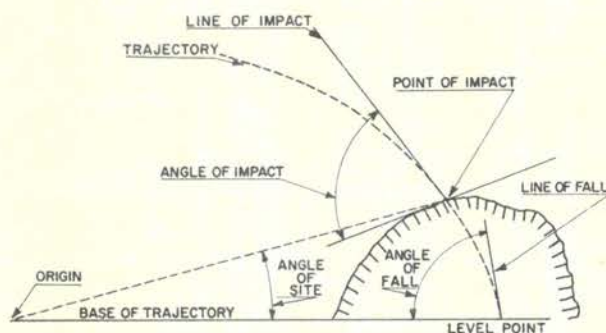


Figure 2-9. Terminal elements of the trajectory

the tube, the muzzle velocity, and gravity. The form would be parabolic with the angle of fall equal to the angle of elevation. The summit would be at a point halfway between the origin and the level point. The trajectory in a vacuum is shown in figure 2-10.

2-17. The Trajectory in the Atmosphere

The resistance of the air to a projectile depends on the air movement, density, and temperature. An assumed density, and temperature structure and a condition of no wind are used as a point of departure for computing firing tables. The air structure so derived is called the standard atmosphere.

2-18. Characteristics of Trajectory in Standard Atmosphere

The most apparent difference between the trajectory in a vacuum and the trajectory in standard atmosphere is the reduction of the range (fig. 2-11). This reduction occurs mainly because, in the atmosphere, the horizontal velocity component is not a constant but is continually decreased by the retarding effect of the air. The vertical velocity

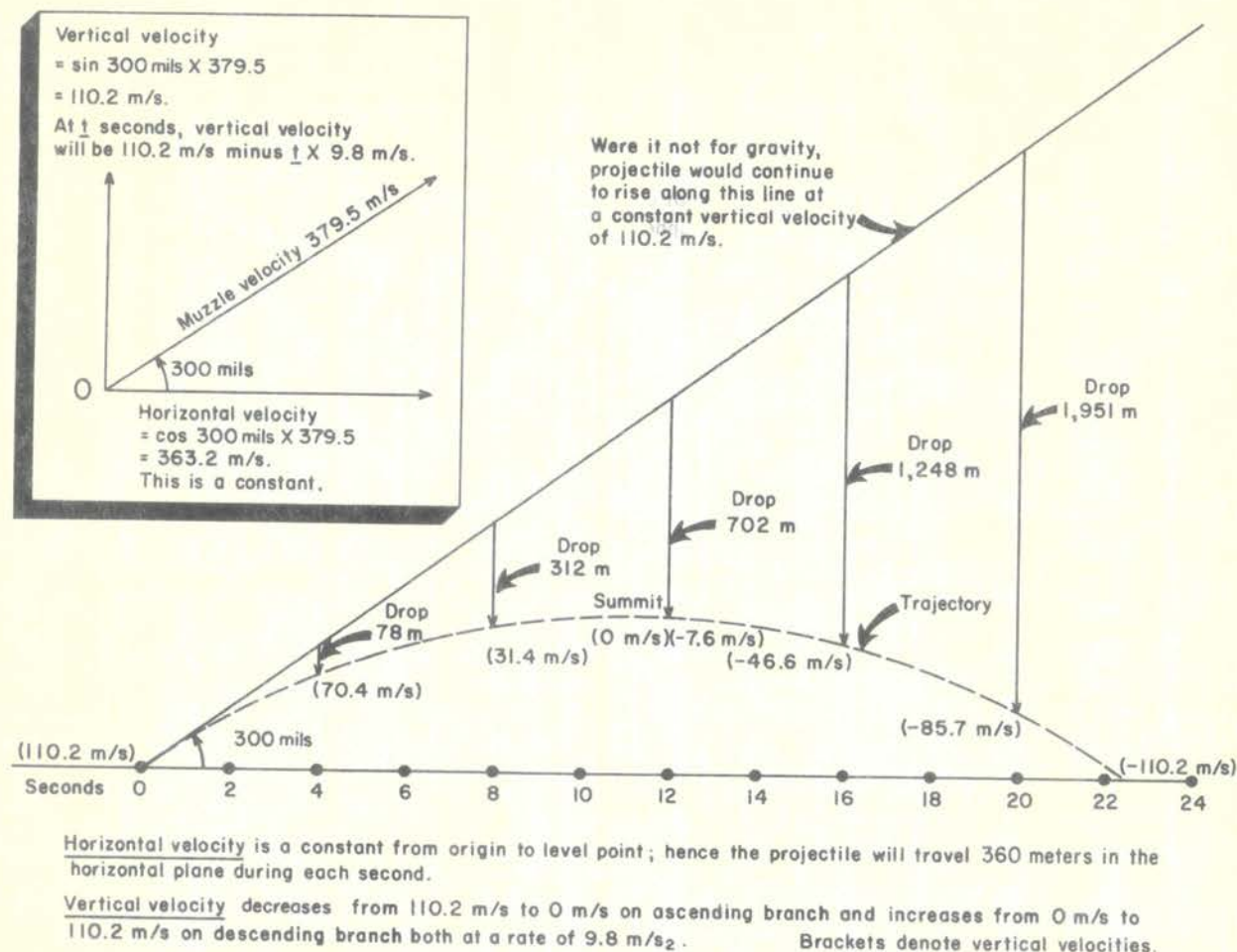


Figure 2-10. Trajectory in a vacuum

component is likewise affected by air resistance. The characteristics of a trajectory in standard atmosphere differ from the characteristics of a trajectory in a vacuum as follows:

a. The velocity at the level point is less than the velocity at origin.

b. The mean horizontal velocity of the projectile beyond the summit is less than the mean velocity before the summit; therefore, the projectile travels a shorter horizontal distance, the descending branch is shorter than the ascending branch, and the angle of fall is greater than the angle of elevation. Also, since the mean vertical velocity is less beyond the summit than before it, the time of descent is greater than the time of ascent.

c. The spin (rotational motion) initially imparted to the projectile causes it to respond differently than in a vacuum because of air resistance.

d. A trajectory in standard atmosphere, as opposed to one in a vacuum, will be shorter and lower after any specific time of flight. This is because—

- (1) *Horizontal velocity* is no longer a constant but decreases with each succeeding time interval.
- (2) *Vertical velocity* is affected not only by gravity but also by the additional retardation effect of the atmosphere.
- (3) The *summit* in a vacuum is midway between the origin and the level point; in the atmosphere, it is nearer the level point.
- (4) The *angle of fall* in a vacuum is equal to the angle of elevation; in the atmosphere, it is greater.

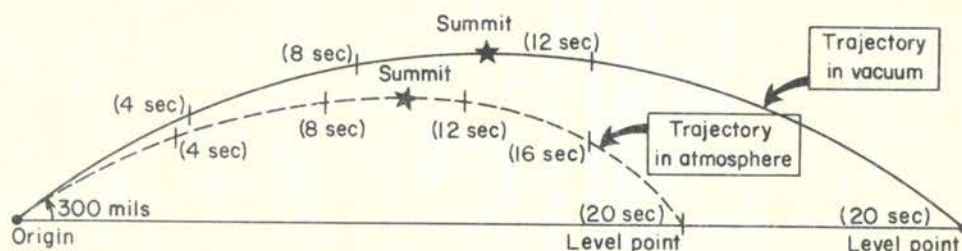
2-19. Standard Conditions and Corrections

a. Certain atmospheric, position, and materiel

A trajectory in standard atmosphere, as opposed to one in a vacuum, will be at a shorter range and at a lower height after any specific time of flight.

This is because —

- (1) Horizontal velocity is no longer a constant but decreases with each succeeding time interval.
- (2) Vertical velocity is affected not only by gravity but also by the additional slowing down from the atmosphere.



Note:

- (1) The summit in a vacuum is midway between the origin and the level point; in the atmosphere, it is nearer the level point.
- (2) The angle of fall in a vacuum is equal to the angle of elevation; in the atmosphere, it is greater.

Figure 2-11. Trajectory in standard atmosphere.

conditions are accepted as standard. These conditions are outlined generally in the introduction to firing tables.

b. When variations from standard conditions are experienced, the trajectory will not conform to the predicted trajectory. Some of these variations can be measured, and corrections can be made to compensate for them. Among the conditions for which corrections may be determined are—

- (1) Difference in altitude between cannon and target.
- (2) Propellant temperature.
- (3) Drift.
- (4) Ballistic wind.
- (5) Differences in muzzle velocity.
- (6) Air temperature.
- (7) Air density.
- (8) Weight of projectile.
- (9) Rotation of the earth.

2-20. Firing Tables

a. Firing tables are based on actual firings of the piece and its ammunition under, or correlated to, a set of conditions defined and accepted as standard. These standards are points of departure used

to compensate for variables in the weapon-weather-ammunition combination that are known to exist at a given instant and location. The atmospheric standards accepted in U.S. firing tables reflect the mean annual condition in the North Temperate Zone.

b. The principal elements measured in experimental firings include angle of elevation, angle of departure, muzzle velocity, attained range, drift, and concurrent atmospheric conditions.

c. The main purpose of a firing table is to provide the data required to bring effective fire on a target under any set of conditions. Data for firing tables are obtained by conducting firings with the weapon at various quadrant elevations. Computed trajectories, based on the equations of motion, are compared with the data obtained in the firings. The computed trajectories are then adjusted to the measured results and data tabulated. Data for elevations not fired are determined by interpolation. Firing table data define the performance of a projectile of known properties under conditions of standard muzzle velocity and weather and a motionless earth.

2-21. Unit Corrections

a. Firing tables describe unit corrections as range correction for an increase (decrease) in muzzle velocity, range wind, air temperature, air density, and projectile weight followed by the appropriate unit value in meters.

b. Each correction is computed on the assumption that all other conditions are standard. Actually, any given correction will differ slightly from that computed if one or more of the other conditions are nonstandard. The amount of differences depends on the effect of the other nonstandard conditions. The effect of one nonstandard condition on the effect of another nonstandard condition is known as an interaction effect. The error introduced by interaction can be reduced by using an electronic computer.

c. Effects and corrections, in meters or mils, are not of equal magnitude when computed at the same range. The relationship between effects and corrections at a given range can be expressed as follows:

$$\text{Corrections} = \frac{\text{standard range}}{\text{standard range} + \text{effects}} \times \text{effects}$$

$$\text{Corrected range} = \frac{\text{standard range}}{\text{standard range} + \text{effects}} \times \text{standard range}$$

For example, an MPI registration is fired by a 155-mm howitzer (M109) firing charge 7, elevation 322 (standard elevation for 10,000 meters). The measured range to the mean point of impact is 9,500 meters. The total effect of all nonstandard conditions is -500 meters. The GFT setting from the MPI registration is GFT A: Charge 7, lot ZT, range 9,500, elevation 322. Using the GFT setting, the elevation to achieve range 10,000 meters is 351 (the elevation for 10,520 meters). The total range correction is +520 meters.

2-22. Extracting Data From Firing Tables

a. The effect of a nonstandard condition is a function of the time the projectile is exposed to that condition. In cannon firing tables, the relationship of corrections to time of flight can be resolved by entering the tables for unit corrections at the chart range plus complementary range.

b. When corrections are being computed, slightly more accurate data can be obtained by making a second computation at the first apparent corrected entry range. (This procedure is called

successive approximation.) However, the improvement is marginal and is not recommended.

c. The weather that affects a projectile as related to the meteorological (met) message is described by the maximum ordinate the projectile achieves. This maximum ordinate is most nearly defined by the quadrant elevation fired.

2-23. Standard Range

a. The standard range is the range opposite a given elevation in the firing tables. It is assumed to be measured along the surface of a sphere concentric with the earth and passing through the muzzle of a weapon. For practical purposes, standard range is the horizontal distance from origin to level point.

b. The attained range is the range which is developed as a result of firing with a certain elevation of the tube. If actual firing conditions duplicate the ballistic properties and meteorological conditions upon which the firing table is based, the attained range and standard range will be equal.

c. The corrected range is that range which corresponds to the elevation that must be fired to reach the target.

2-24. Effect of Nonstandard Conditions

a. Deviations from standard conditions, if not corrected for in computing firing data, will cause the projectile to impact or burst at some point other than the desired point.

b. Corrections for nonstandard conditions are made to improve accuracy. The accuracy of artillery fires depends on the accuracy and completeness of the data available, computational procedures used, and care in laying the pieces. Accuracy should not be confused with precision. Precision is related to tightness of the dispersion pattern without regard to its proximity to a desired point. Accuracy is related to the location of the mean point of impact with respect to a desired point.

2-25. Range Effects

a. Vertical jump is the angle formed by the lines of elevation and departure. The shock of firing causes a momentary vertical and rotational movement of the tube prior to the ejection of the projectile. Vertical jump has the effect of a small change in elevation. The effect of vertical jump depends mainly on the eccentricity of the center of gravity of the recoiling parts with respect to the axis of

the bore. In modern weapons, vertical jump cannot be predicted and is usually small. For these reasons, vertical jump is not considered separately in the gunnery problem; it is a minor contributing factor to range dispersion.

b. Droop is the algebraic sum of barrel curvature, untrueness of the breech quadrant seats, and untrueness in assembling the tube to the breech. Its magnitude is defined as the difference between the elevation measured at the muzzle and the elevation measured on the breech quadrant seats. Firing tables are constructed on the basis of measurements at the muzzle. For example, if droop for a certain weapon is -3 mils and an elevation of 360 is set in the normal manner, the tube elevation is only 357 mils; if it is desired to fire a tube 360-mil elevation, a setting of 363 would be necessary. On most weapons droop is absorbed into the computed velocity error, although in reality it is an elevation error.

c. Muzzle velocity is the speed of the projectile at the time it is projected from the muzzle; the greater the velocity of a given projectile, the greater the attained range. Velocity error often becomes a catchall for many nonvelocity elements. When this occurs, accuracy is adversely affected in subsequent applications of the velocity error.

d. The weight of the projectile affects muzzle velocity. Two opposing factors affect the flight of a projectile of nonstandard weight. A heavier projectile is more efficient in overcoming air resistance; however, because it is more difficult to push through the tube, its muzzle velocity is normally lower. An increase in projectile efficiency increases range, but a decrease in muzzle velocity decreases range. In firing tables, corrections for these two opposing factors are combined into a single correction. The change in muzzle velocity predominates at shorter times of flight; the change in projectile efficiency predominates at longer times of flight. Hence, for a heavier than standard projectile, the correction is plus at the shorter times of flight and minus at the longer times of flight. The reverse is true for a lighter than standard projectile.

e. Air resistance affects the flight of the projectile both in range and direction. The compo-

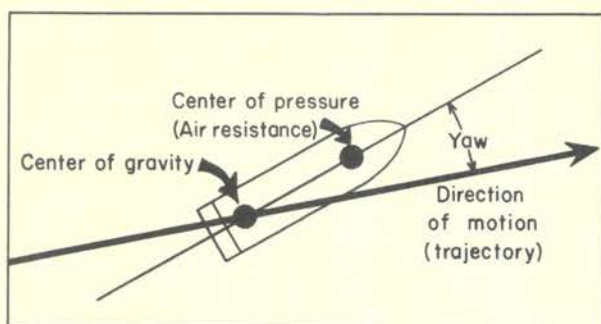
nent of air resistance in the direction opposite to that of the forward motion of the projectile is called drag. Because of drag, both the horizontal and vertical components of velocity are less at any given time of flight than they would be if drag were zero, as in a vacuum. This decrease in velocity varies directly in magnitude with drag and inversely with the mass of the projectile. This means, in terms of attained range, the greater the drag, the shorter the range; and the heavier the projectile, the longer the range—all other factors being equal. Several factors considered in the computation of drag are—

(1) *Air density*. The drag of a given projectile is proportional to the density of the air through which it passes. For example, an increase in air density by a given percentage increases the drag by the same percentage. Since the air density at a particular place, time, and altitude varies widely, the standard trajectories reflected in the firing tables are computed with a fixed relation between density and altitude.

(2) *Velocity*. The faster a projectile moves, the more the air resists its motion. Examination of a set of firing tables shows that for a constant elevation, the effect of 1 percent air density (hence 1 percent drag) increases with an increase of charge; that is, muzzle velocity. The drag is approximately proportional to the square of the velocity except in the vicinity of the velocity of sound. There the drag increases more rapidly because of the increase in pressure behind the sound wave.

(3) *Diameter*. Two projectiles of identical shape but different size will not experience the same drag. For example, a large projectile will offer a large area for the air to act upon; hence its drag will be increased by this factor. The drag of projectiles of the same shape is proportional to the square of the diameter.

★(4) *Drag coefficient*. The drag coefficient combines several ballistic properties of typical projectiles. These properties include yaw (the angle between the direction of motion of the projectile and the axis of the projectile (fig. 2-12) and the mach number (the ratio of the velocity of the projectile to the speed of sound (fig. 2-13)).



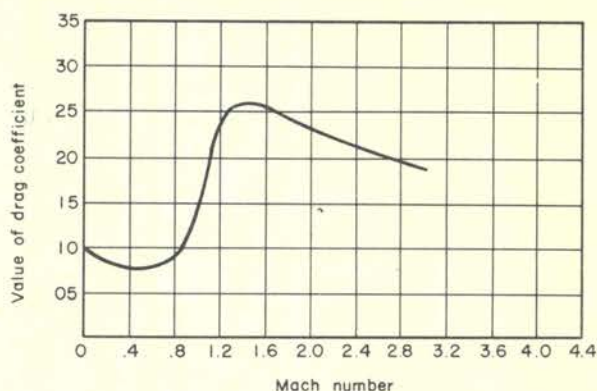
(Air resistance is least when center of pressure is on the trajectory; that is, zero yaw)

★Figure 2-12. Yaw of projectile in flight.

f. The shell surface finish affects muzzle velocity. A rough surface on the projectile or fuze will increase air resistance, thereby decreasing range.

g. The ballistic coefficient of a projectile relates its efficiency in overcoming air resistance to that of an assumed standard projectile. For ease in computations, all projectile types are classified into certain standard groups. Each projectile, however, has its own efficiency level. Each projectile lot has its own average efficiency level; that is, ballistic coefficient. In order to establish firing tables, it is necessary to select and fire one specific projectile lot. Based on the performance of this lot, standard ranges are determined. The ballistic coefficient of this particular projectile lot becomes the firing table standard. However, other projectile lots of the same type may not have the same ballistic coefficient as the one reflected in the firing tables. If one of the other lots is more efficient, that is, has a higher ballistic coefficient than the firing table standard, it will achieve a greater range when fired. The reverse is true for a less efficient projectile lot. In present gunnery procedures, variations in ballistic coefficient are considered an element of muzzle velocity.

★h. As the air temperature increases, the drag decreases, thereby increasing range. This does not hold true as the projectile approaches the speed of sound. Here drag is related to the mach number and the relationship changes abruptly in the vicinity of mach 1.



1. Mach number = $\frac{\text{velocity of projectile}}{\text{speed of sound}}$

2. The speed of sound is faster in warmer air; hence an increase (decrease) in air temperature decreases (increases) the Mach number.
3. A change in the Mach number can change the value of the drag coefficient either upward or downward, depending on the Mach number at which the change occurs.
4. An increase (decrease) in the value of the drag coefficient decreases (increases) the developed range.

★Figure 2-13. Effect of velocity (mach number) on drag coefficient of projectile type 1.

i. Air density effects have been previously discussed as directly related to drag, with the more dense air offering greater resistance and vice versa.

j. Range wind is that component of the ballistic wind blowing parallel to the direction of fire and in the plane of fire. The plane of fire is a vertical plane that contains the line of elevation. Range wind changes the relationship between the velocity of the projectile and the velocity of the air near the projectile. If the air is moving with the projectile (tailwind), it offers less resistance to the projectile and a longer range results; a headwind has the opposite effect.

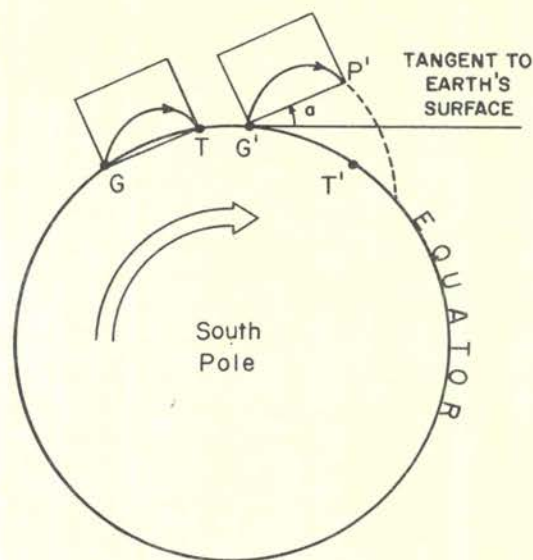
k. Although the earth rotates at a constant rate, the correction for rotation varies with a number of factors and, therefore, rotation is more readily considered a nonstandard condition. Factors influencing the effect of rotation of the earth on the travel of a projectile are direction of fire, angle of departure, velocity of projectile, range to the target, and the latitude of the gun. Corrections for these factors are

combined in convenient tabular form in firing tables. The correction tables provide all the data needed to compensate for rotation in the gunnery problem. However, some background theory of rotational effects may assist in an understanding of ballistics.

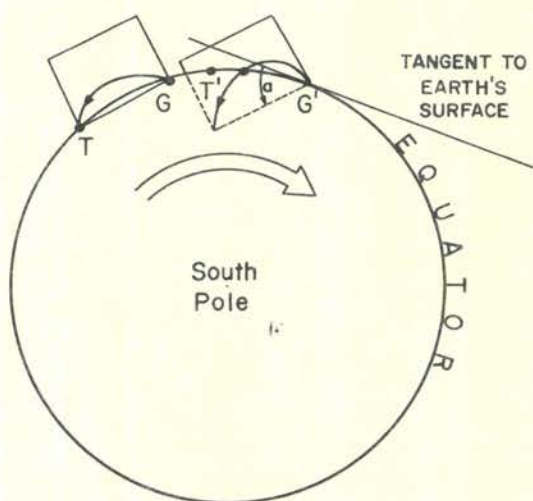
(1) Because of rotation of the earth, a point on the Equator has an eastward linear velocity of approximately 457 meters per second. This linear velocity decreases to zero at either pole. Consider a gun on the

Equator firing due east at a target (Example ①, fig. 2-14. During the time of flight of the projectile, the gun and target will travel from G to G' and T to T', respectively, along the circumference of the earth. The projectile, however, travels in a vertical plane, the base of which is parallel to the original plane of departure established at the time of firing; that is, it is pivotal to the circumference of the earth at the gun but not at the target. At the end of a given time of flight, the projectile will be at P' when the target is at T'. Hence, the projectile will continue along an extended trajectory and land farther east or, in this instance, beyond the target. The normal trajectory of the projectile is interrupted. Consider the same gun firing westward (Example ②, fig. 2-14. Again, the projectile falls to the east of the target, but in this instance east is short. The effect in each example is as if the quadrant elevation fired has been in error by the amount of angle a , which is the angle formed by the base line G'P' and a tangent to the earth at G'. When the gun is firing eastward, angle a is plus (range over); when the gun is firing westward, angle a is minus (range short).

- (2) A second consideration is the curvature effect. Curvature effect exists because of the use of a map range for which the surface of the earth is assumed to be flat, but the actual range is measured on a sphere. The gun-target (GT) range is computed for a plane tangent to the surface of the earth at the gun. When the projectile reaches this range, it is still above the curved surface of the earth and will continue to drop, resulting in a slightly longer true range than desired. This effect is of little significance except at very long ranges. It is disregarded when firing tables are used, since firing table ranges include curvature effect.
- (3) A final rotational effect is described as the latitudinal effect. When the gun and target are at different latitudes, the eastward rotational velocity imparted to the pro-



① Rotational effects on range firing eastward



② Rotational effects on range firing westward

Figure 2-14. Rotational effects

jectile and the target are different. For example, if the gun is nearer the Equator (Example ①, fig. 2-15, the projectile will travel faster and therefore farther to the east than the target (the effect left or right depends on the hemisphere). When the gun and target are at the same latitude (Example ②, fig. 2-15), the projectile will also be deflected away from the tar-

get. This is because the projectile tends to travel in the plane of the great circle containing the gun and target at the time of firing. Because of the rotation of the earth, this great circle plane is continuously changing with respect to its original position. As viewed from above, it would appear that the great circle containing the gun and target is turning with respect to the great circle followed by the projectile. An additional latitudinal effect is pictured in (Example ③, fig. 2-15). When the latitude is other than the Equator, the projectile is pulled out of its original vertical plane by the force of gravity which operates from the center of the earth and not on a perpendicular to the axis of the earth.

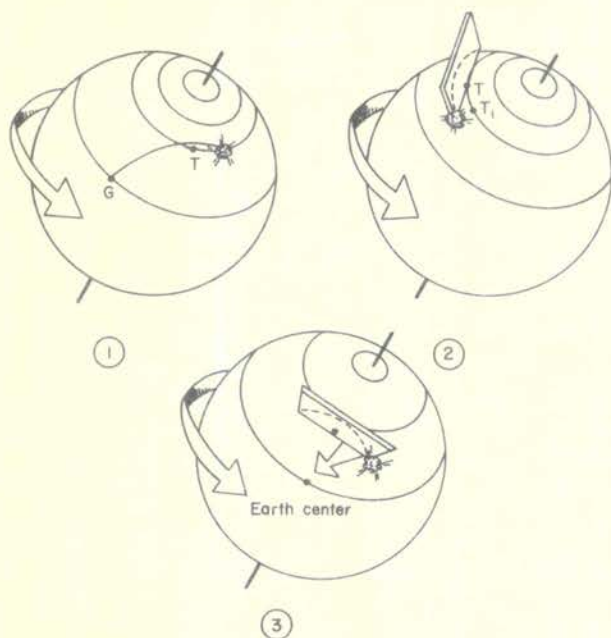


Figure 2-15. Latitudinal effect

2-26. Deflection Effects

a. Lateral jump is caused by a slight lateral and rotational movement of the tube at the instant of firing. It has the effect of a small error in deflection. The effect is ignored, since it is small and varies from round to round.

b. Drift is defined as the departure of the pro-

jectile from standard direction because of the combined action of air resistance, projectile spin, and gravity. In order to fully understand the forces that cause drift, it is necessary to understand the angle of yaw, which is that angle between the direction of motion of the projectile and the axis of the projectile. The direction of this angle is constantly changing in a spinning projectile—right, down, left, and up. This initial yaw is at a maximum near the muzzle and gradually subsides as the projectile stabilizes. The atmosphere offers greater resistance to a yawing projectile; therefore, it is fundamental in the design of projectiles that yaw be kept to a minimum and be quickly damped out in flight. At the summit, where the descending branch of the trajectory begins, summital yaw is introduced and the effect on the projectile is to keep the nose pointed slightly toward the direction of the spin. Therefore, since artillery projectiles have a clockwise spin, they drift to the right in the descending branch of the trajectory. The magnitude of drift (expressed as lateral distance on the ground) depends on the time of flight and rotational speed of the projectile and the curvature of the trajectory.

c. The crosswind is that component of the ballistic wind blowing across the direction of fire. Crosswind tends to carry the projectile with it and causes a deviation from the direction of fire. However, the lateral deviation of the projectile is not as great as the movement of the air causing it. Wind component tables simplify the reduction of a ballistic wind into its two components with respect to the direction of fire.

d. The effects on deflection from the rotation of the earth are described in paragraph 2-25*k*(3) and figure 2-15.

2-27. Time of Flight

a. Those nonstandard conditions which affect range also affect time of flight. Also, the fuze settings for current time fuzes, although approximating time of flight, are not interchangeable with the time of flight.

b. In some firing tables such as FT 155-Q-3, corrections to fuze setting are not computed separately from corrections to elevation. When using such firing tables, fuze setting is treated as a function of elevation plus complementary angle of site.

Section IV. DISPERSION AND PROBABILITY

2-28. General

a. If a number of rounds of the same caliber and same lot of ammunition are fired from the same weapon with the same settings in quadrant elevation and deflection, the rounds will not all fall at a single point but will be scattered in a pattern of bursts. In discussions of artillery fire, the natural phenomenon of change is called dispersion. The array of the bursts on the ground is the dispersion pattern.

b. The points of impact of the projectiles will be scattered both laterally (deflection) and in depth (range). Dispersion is the result of minor variations of many elements from round to round and must not be confused with variations in point of impact caused by mistakes or constant errors. Mistakes can be eliminated and constant errors compensated for. Those inherent errors which are beyond control and cause dispersion are caused in part by—

- (1) *Conditions in the bore.* Muzzle velocity is affected by minor variations in weight, moisture content, and temperature of the propelling charge; variations in the arrangement of the powder grains; differences in the ignition of the charge; differences in the weight of the projectile and in the form of the rotating bands; variations in ramming; and variations in the temperature of the bore from round to round. Variations in the bourrelet and rotating band may cause inaccurate centering of the projectile and, hence, inaccurate flight.
- (2) *Conditions in the carriage.* Direction and elevation are affected by play (looseness) in the mechanisms of the carriage, physical limitations on precision in setting scales, and nonuniform reaction to firing stresses.
- (3) *Conditions during flight.* Air resistance is affected by differences in weight, velocity, and form of projectile and by changes in wind, density, and temperature of the air from round to round.

2-29. Mean Point of Impact

For any large number of rounds fired, it is pos-

sible to draw diagram showing a line perpendicular to the line of fire that will divide the points of impact into two equal groups. Half of the rounds considered will be beyond the line, or *over* when considered from the weapon; half will be inside the line, or *short* when considered from the weapon. For this same group of rounds there will also be a line parallel to the line of fire that will divide the rounds equally. Half of the rounds will fall to the right of the line; half will fall to the left of the line. The first line, perpendicular to the line of fire, represents the mean range; the second line, parallel to the line of fire, represents the mean deflection. The intersection of the two lines is the mean point of impact (fig. 2-16).

2-30. Probable Error

Consider for a moment only the rounds that have fallen over (or short) of the mean point of impact. There is some point along the line of fire, beyond the mean point of impact, at which a second line perpendicular to the line of fire can be drawn that will divide the overs into two equal parts (line AA, fig. 2-17). All of the rounds beyond the mean point of impact manifest an error in range—they are all *over*. Some of the rounds falling *over* are more in error than others. If the distance from the mean point of impact to line AA is a measure of error, it is clear that half of the rounds over have a greater error and half of the rounds over have a lesser error. The distance from the mean point of impact to line AA thus becomes a convenient unit of measure. This distance is called one probable error. The most concise definition of a probable error is that it is the error which is exceeded as often as it is not exceeded.

2-31. Dispersion Pattern

The distribution of rounds in a normal burst pattern will be the same number of rounds short of the mean point of impact (MPI) as the number of rounds over the mean point of impact. The probable error will be the same in both cases.

a. It is a coincidence of nature that for any normal distribution (such as artillery fire) a distance of 4 probable errors on either side of the mean point of impact will include virtually all of the rounds in the pattern. This is not precisely true, since a very small fraction of the rounds (approx-

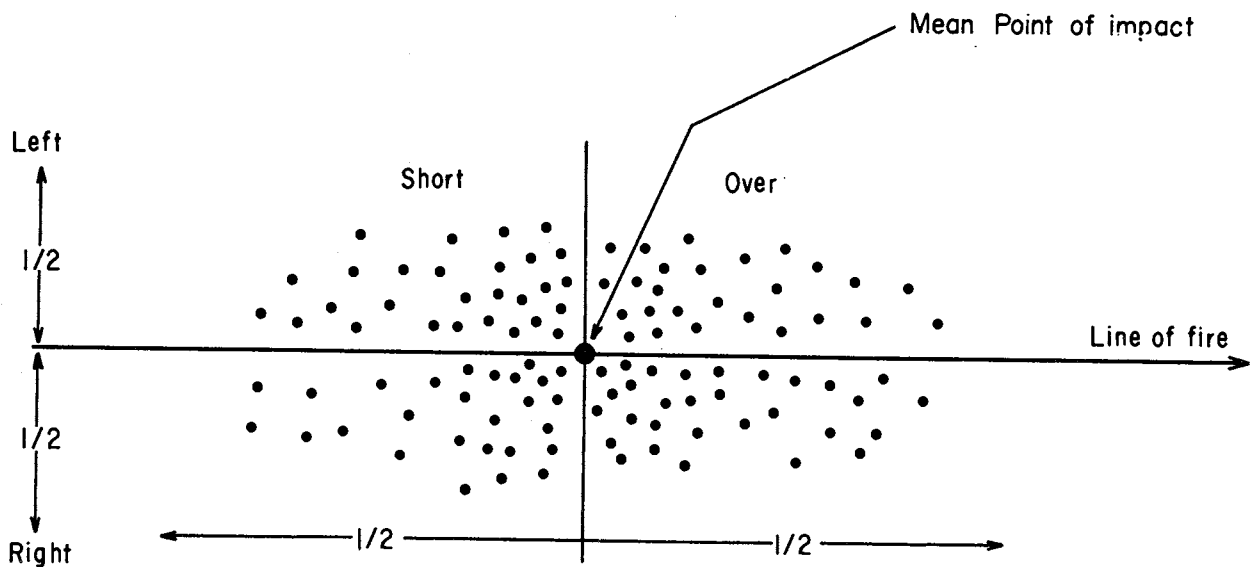


Figure 2-16. Dispersion

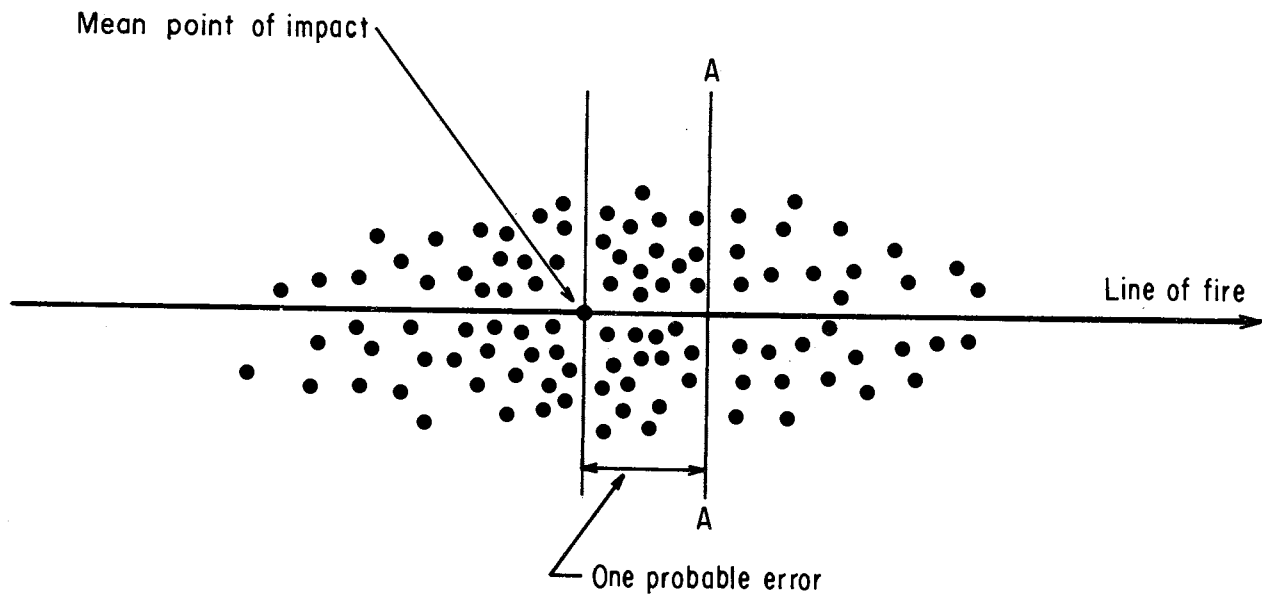


Figure 2-17. Range probable error

imately 7 out of 1,000) will fall outside 4 probable errors on either side of the mean point of impact but it is true for all practical purposes.

b. The total pattern of a large number of bursts is roughly elliptical (fig. 2-17). However, using the fact that 4 probable errors on either side of the mean point of impact (in range and in deflection) will encompass virtually all rounds, a rectangle normally is drawn to include the full

distribution of the rounds. This rectangle is the 100-percent rectangle (fig. 2-18).

2-32. Dispersion Scale

If 1 probable error is used as the unit of measurement to divide the dispersion rectangle evenly into eight zones in range, the percentage of rounds falling in each zone will be as indicated in figure 2-18. By definition of probable error, the 50 per-

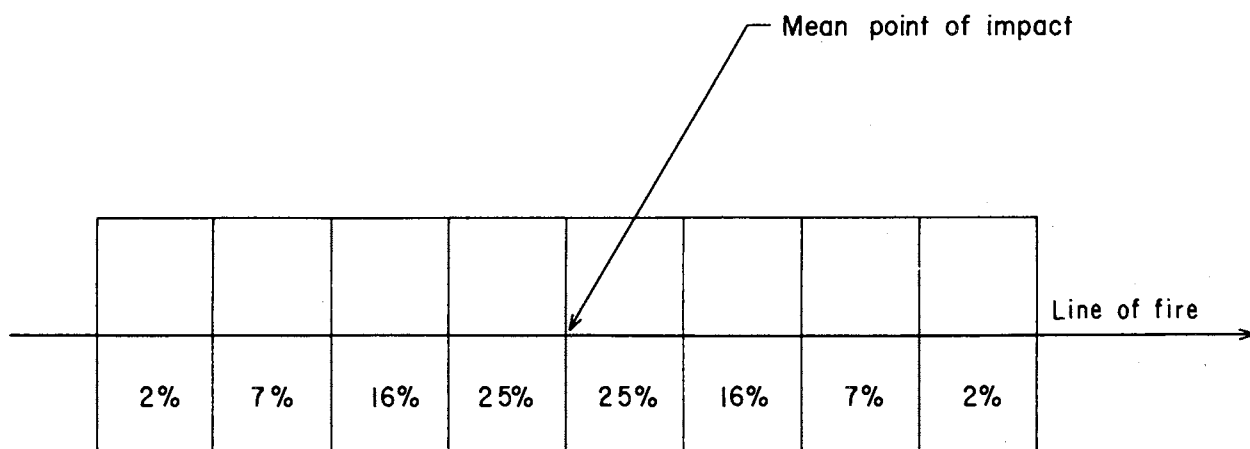


Figure 2-18. The 100-percent rectangle

cent of rounds nearest the mean range line (line through the mean point of impact) fall within 1 probable error. The other percentages have been found to be true by experiment. Again, what is true in range will be true also in deflection. If range dispersion zones and deflection dispersion zones are both considered, a set of small rectangles is created. The percent of the rounds falling in each rectangle is shown in figure 2-19.

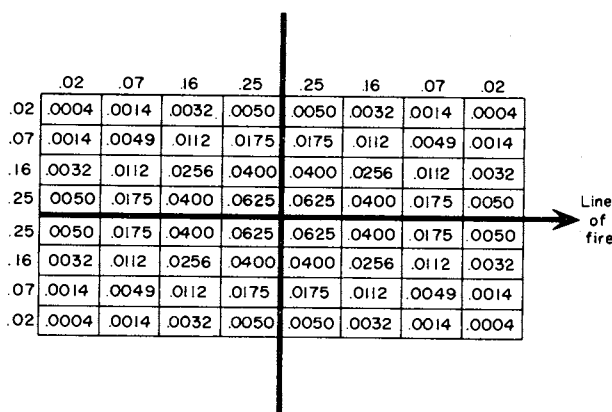


Figure 2-19. Dispersion rectangle

2-33. Normal Probability Curve

a. The dispersion of artillery projectiles follows the laws of probability and normal distribution. The pattern of bursts on the ground can be graphed with a normal probability curve, a common method of representing the probability of the occurrence of an error of any given magnitude in a series of samples.

b. Distances of points on the horizontal (base)

line (fig. 2-20) measured to the right and left of the center represent errors in excess (over) or in deficiency (short). The area under the curve enclosed by vertical lines cutting the base line and the curve represents the probability of the occurrence of an error within the magnitudes represented by the ends of the base line segment considered. In figure 2-20 the shaded area represents the number of rounds falling over and within 1 probable error of the mean point of impact, which is 25 percent.

c. The curve (fig. 2-20) expresses the following facts:

- (1) In a large number of samples, errors in excess and errors in deficiency are equally frequent (probable), as shown by the symmetry of the curve.
- (2) The errors are not uniformly distributed. The smaller errors occur more frequently than the larger errors, as shown by the greater height of the curve in the middle.

2-34. Range Probable Error

The approximate value of the probable error in range (PE_r) is shown in the firing tables and can be taken as an index of the precision of the piece. Firing table values for probable errors are based on the firing of specific ammunition under controlled conditions. The actual round-to-round probable error experienced in the field will normally be larger.

2-35. Fork

Fork is the term used to express the change in

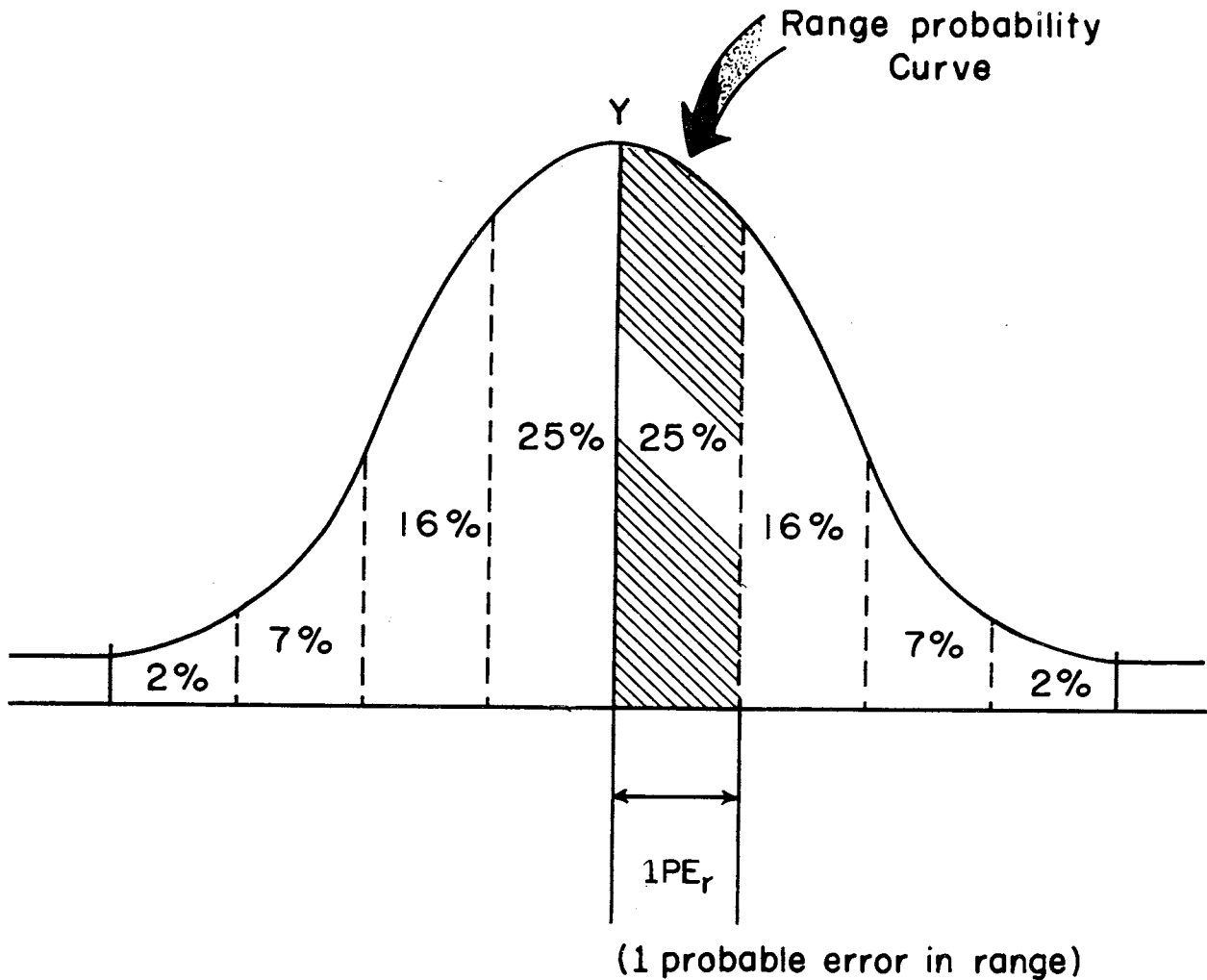


Figure 2-20. Areas under the normal probability curve

elevation in mils necessary to move the mean point of impact 4 range probable errors. The value of the fork is given in the firing tables. For example, for a 155-mm howitzer (M109) firing charge 5 green bag at a range of 6,000 meters, the fork is 3 mils.

2-36. Deflection Probable Error

The value of the probable error in deflection (PE_d) is given in the firing tables. For cannons, the deflection probable error is considerably smaller than the range probable error. For example, for a 155-mm howitzer (M109) firing charge 5 green bag at a range of 5,000 meters, the deflection probable error is 2 meters. In other words, 50 percent of the projectiles fired will hit within 2 meters, 82

percent will hit within 4 meters, and 96 percent will hit within 6 meters of the mean deflection.

2-37. Vertical Probable Error

The range probable error given in the firing tables is based on firing on a horizontal plane. If the target is a vertical surface (or even a steep incline), the probable error for range will be different. If the target is truly vertical, the probable error against the target surface is equal to the range probable error divided by the cotangent of the angle of fall (fig. 2-21). Precise computation of the size of the probable error against a vertical or steep surface is seldom made. It suffices to recognize that the vertical dispersion is a function of the range dispersion, the angle of fall, and the

angle of the target surface with respect to the horizontal. Except in high-angle fire, the vertical probable error (PE_v) will normally be smaller than the range probable error.

★2-38. Airburst Probable Errors

a. Time to Burst Probable Error. The value of probable error in time to burst (PE_T) is shown in the firing tables and can be taken as the weighted average (root mean square) of the precision of the timing mechanism of the fuze and the actual time of flight of the projectile. For example, for a 155-mm howitzer (M109) firing charge 5 green bag at a range of 5,000 meters, the time to burst probable error is 0.11 second for the M564 fuze. As in any other normal dispersion pattern, 50 percent of the projectiles fired with fuze M564 will burst within ± 0.11 second, 82 percent within ± 0.22 second, and 96 percent within ± 0.33 second of the mean time.

b. Height of Burst Probable Error. When the projectile is fuzed to burst in the air, the probable error in height of burst (PE_H) is the vertical component of one time to burst probable error (PE_T) times the vertical component of velocity. Values of the height of burst probable error for a particular time fuze are given in the firing tables. Height of burst probable error for variable time (VT) fuze cannot be predicted because the height of burst varies with the angle of fall of the projectile and the type of terrain over which the projectile is passing. The height of burst probable error for fuze VT can be estimated by observing and analyzing results obtained from firing over a given terrain.

c. Range to Burst Probable Error. When the projectile is fuzed to burst in the air, the total probable error in range to burst (PE_R) is the horizontal component of one time to burst probable error (PE_T) times the horizontal component of velocity.

2-39. Application of Probable Errors

a. Normal distribution is expressed in terms of probable errors (PE's), because the distribution of bursts about the mean is the same regardless of the magnitude of the probable error. Firing tables list probable errors for range, deflection, height of burst, and time to

burst at each listed range. It is possible to express a given distance in terms of probable errors and solve problems by using the dispersion scale or probability tables.

b. To compute the probability of a round landing within an error of a certain magnitude, reduce the specified error to equivalent probable errors in one direction along the dispersion scale, and multiply the sum by 2. For example, a 155-mm howitzer (M109) has fired a number of rounds with charge 7, and the mean point of impact has been determined to be at 11,500 meters. What is the probability that the next round fired will fall within 60 meters of the mean point of impact?

Solution:

Range PE at 11,500 meters (charge 7) = 30 meters.

Equivalent of 60 meters in PE's ($60/30$) = 2.

Percent of rounds falling within 2 PE =

2 (25% + 16%) = 82% (fig. 2-18).

2-40. Probability Tables

The computation of probability is simplified by the use of a probability table (table 2-2).

a. The entire area under the normal probability curve is unity, or 100 percent. The ratio of any particular portion of the area to the total area represents the probability that the burst in question will occur within the interval over which the particular area stands. For example, consider that portion of the total area which stands over the interval from the mean to a distance of 1 probable error on one side of the mean. This is 25 percent of the total area under the curve. Numbers in the body of the table are areas under the normal probability curve. The arguments are distances, expressed in probable errors. In the first vertical column are distances, expressed in probable errors to the nearest tenth; horizontally across the top of the table is the breakdown in hundredths of probable errors. Entry into the table is similar to entry into a table of logarithms. The total area under the probability curve is taken as one. Note that the maximum area defined in the body of the table is 0.5000, or 50 percent, or one-half. Therefore, the numbers in the body of the table actually give the probability that the event in question will occur within various probable errors from the mean and on one side only of the mean. Interpolation in the

$$\text{COTANGENT } \omega = \frac{1 \text{ PE}_r}{1 \text{ PE}_h}$$

THEREFORE:

$$1 \text{ PE}_h = \frac{1 \text{ PE}_r}{\text{COTANGENT } \omega}$$

1 VERTICAL PROBABLE
ERROR (PE_h)1 RANGE PROBABLE ERROR (PE_r)ASSUME THAT TERMINAL END OF
TRAJECTORY IS A STRAIGHT LINEANGLE OF FALL (ω)

★Figure 2-21. Vertical dispersion.

tables is an unnecessary refinement. A complete set of probabilities for one side of the mean is shown in table 2-2.

b. The example in paragraph 2-39b can be solved by the use of the probability table as follows:

Equivalent PE's 2.0
Value from table 2-2 0.4113.

Probability (0.4113×2) 82.26 percent.

The answer differs slightly from that obtained by using the dispersion scale because probability tables are to an accuracy of four decimal places and are entered with probable error expressed to the hundredth, whereas the dispersion scale is to

Table 2-2. Normal Probability Table, Areas of the Normal Probability Curve
(*t* is expressed in probable errors.)

<i>t</i>	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	0.0000	0.0027	0.0054	0.0081	0.0108	0.0135	0.0162	0.0189	0.0216	0.0243
0.1	.0269	.0296	.0323	.0350	.0377	.0404	.0431	.0457	.0484	.0511
0.2	.0538	.0565	.0591	.0618	.0645	.0672	.0699	.0725	.0752	.0778
0.3	.0804	.0830	.0856	.0882	.0908	.0934	.0960	.0986	.1012	.1038
0.4	.1064	.1089	.1115	.1140	.1166	.1191	.1217	.1242	.1268	.1293
0.5	.1319	.1344	.1370	.1395	.1421	.1446	.1472	.1497	.1522	.1547
0.6	.1572	.1597	.1622	.1647	.1671	.1695	.1719	.1743	.1767	.1791
0.7	.1815	.1839	.1863	.1887	.1911	.1935	.1959	.1983	.2007	.2031
0.8	.2054	.2077	.2100	.2123	.2146	.2169	.2192	.2214	.2236	.2258
0.9	.2280	.2302	.2324	.2346	.2368	.2390	.2412	.2434	.2456	.2478
1.0	.2500	.2521	.2542	.2563	.2584	.2605	.2626	.2647	.2668	.2689
1.1	.2709	.2730	.2750	.2770	.2790	.2810	.2830	.2850	.2869	.2889
1.2	.2908	.2927	.2946	.2965	.2984	.3003	.3022	.3041	.3060	.3078
1.3	.3097	.3115	.3133	.3151	.3169	.3187	.3205	.3223	.3240	.3258
1.4	.3275	.3292	.3309	.3326	.3343	.3360	.3377	.3393	.3410	.3426
1.5	.3442	.3458	.3474	.3490	.3506	.3521	.3537	.3552	.3567	.3582
1.6	.3597	.3612	.3627	.3642	.3657	.3671	.3686	.3700	.3714	.3728
1.7	.3742	.3756	.3770	.3784	.3798	.3811	.3825	.3838	.3851	.3864
1.8	.3877	.3890	.3903	.3915	.3928	.3940	.3952	.3964	.3976	.3988
1.9	.4000	.4012	.4024	.4035	.4047	.4058	.4069	.4080	.4091	.4102
2.0	.4113	.4124	.4135	.4146	.4156	.4167	.4177	.4187	.4197	.4207
2.1	.4217	.4227	.4237	.4246	.4256	.4265	.4274	.4283	.4292	.4301
2.2	.4310	.4319	.4328	.4336	.4345	.4353	.4361	.4369	.4377	.4385
2.3	.4393	.4401	.4409	.4417	.4425	.4433	.4441	.4448	.4456	.4463
2.4	.4470	.4477	.4484	.4491	.4498	.4505	.4512	.4519	.4526	.4533
2.5	.4540	.4547	.4553	.4560	.4566	.4572	.4578	.4584	.4590	.4596
2.6	.4602	.4608	.4614	.4620	.4625	.4630	.4636	.4641	.4646	.4651
2.7	.4657	.4662	.4667	.4672	.4677	.4682	.4687	.4692	.4697	.4701
2.8	.4705	.4710	.4714	.4718	.4722	.4727	.4731	.4735	.4739	.4743

Table 2-2. Normal Probability Table, Areas of the Normal Probability Curve—Continued
(*t* is expressed in probable errors.)

<i>t</i>	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
2.9	.4748	.4752	.4756	.4760	.4764	.4768	.4772	.4776	.4780	.4783
3.0	.4787	.4790	.4793	.4796	.4800	.4803	.4806	.4809	.4812	.4815
3.1	.4818	.4821	.4824	.4827	.4830	.4833	.4836	.4839	.4842	.4845
3.2	.4848	.4851	.4853	.4855	.4857	.4859	.4862	.4864	.4866	.4868
3.3	.4870	.4873	.4875	.4877	.4879	.4881	.4883	.4885	.4886	.4888
3.4	.4890	.4892	.4893	.4895	.4897	.4899	.4901	.4902	.4904	.4906
3.5	.4908	.4909	.4911	.4913	.4915	.4916	.4917	.4919	.4921	.4922
3.6	.4923	.4924	.4926	.4927	.4928	.4929	.4931	.4933	.4934	.4935
3.7	.4936	.4938	.4939	.4940	.4941	.4942	.4944	.4945	.4946	.4947
3.8	.4948	.4949	.4950	.4951	.4952	.4953	.4953	.4954	.4955	.4956
3.9	.4957	.4958	.4959	.4960	.4960	.4961	.4962	.4963	.4964	.4965
4.0	.4965	.4966	.4967	.4967	.4968	.4969	.4969	.4970	.4971	.4972
4.1	.4972	.4973	.4973	.4974	.4974	.4975	.4975	.4976	.4976	.4977
4.2	.4978	.4978	.4979	.4979	.4980	.4980	.4980	.4981	.4981	.4981
4.3	.4982	.4982	.4982	.4983	.4983	.4983	.4983	.4984	.4984	.4985
4.4	.4985	.4985	.4986	.4986	.4986	.4987	.4987	.4987	.4988	.4988
4.5	.4988	.4989	.4989	.4989	.4989	.4990	.4990	.4990	.4990	.4991
4.6	.4991	.4991	.4991	.4991	.4992	.4992	.4992	.4992	.4992	.4992
4.7	.4993	.4993	.4993	.4993	.4993	.4993	.4994	.4994	.4994	.4994
4.8	.4994	.4994	.4994	.4995	.4995	.4995	.4995	.4995	.4995	.4995
4.9	.4995	.4996	.4996	.4996	.4996	.4996	.4996	.4996	.4996	.4996
5.0	.4996	.4996	.4997	.4997	.4997	.4997	.4997	.4997	.4997	.4997
5.1	.4997	.4997	.4997	.4997	.4998	.4998	.4998	.4998	.4998	.4998
5.2	.4998	.4998	.4998	.4998	.4998	.4998	.4998	.4998	.4998	.4998
5.3	.4998	.4998	.4998	.4998	.4998	.4998	.4999	.4999	.4999	.4999
5.4	.4999	.4999	.4999	.4999	.4999	.4999	.4999	.4999	.4999	.4999
5.5	.4999	.4999	.4999	.4999	.4999	.4999	.4999	.4999	.4999	.4999
5.6	.4999	.4999	.4999	.4999	.4999	.4999	.4999	.4999	.4999	.4999
5.7	.4999	.4999	.4999	.4999	.4999	.4999	.4999	.4999	.4999	.4999
5.8	.5000	.5000	.5000	.5000	.5000	.5000	.5000	.5000	.5000	.5000
5.9	.5000	.5000	.5000	.5000	.5000	.5000	.5000	.5000	.5000	.5000

an accuracy of only two decimal places and is entered with whole probable errors. Probability tables provide the more accurate answer.

c. In some problems, the probability is required for only one side of the mean in which case the multiplication by 2 is omitted. For example, to determine the probability that a burst will be closer to the ground than 100 meters when the mean height of burst is 350 meters above the ground and the height of burst probable error (PE_h) is 75 meters, the following procedures are used:

Specified error (meters) = $350 - 100 = 250$; 250 meters below the mean is 100 meters above ground.

Error in $PE_h = 250/75 = 3.33$.

From probability table 2-2, 3.33 corresponds to 0.4877, which is the probability that the burst will be between the mean and 100

meters above the ground. Since the total probability for a burst being below the mean is 0.5000, then the probability of a burst being less than 100 meters above the ground, that is, more than 250 meters below the mean, is $0.5000 - 0.4877 = 1.23$ percent.

By extension, the probability that the burst will occur at either less than 100 meters above the ground (250 below the mean) or more than 600 meters above the ground (250 above the mean) is 1.23 percent $+ 1.23$ percent = 2.46 percent. Any combination of limiting height above the ground can be similarly solved. The maximum and minimum limits specified need not reduce the same error from the mean as in the foregoing example. Each is solved independently, and the probabilities are added.

d. It is emphasized that the probability tables give the probability of not exceeding a certain error or, by subtraction, the probability of making an error equal to or less than a specified error. The probability tables cannot give the probability of making a particular error. Though there is little application for the computation in artillery, a computation could be made to give the probability of making an error falling within a prescribed range. By combining some of the computations already discussed, it would be relatively simple to determine the probability of making an error greater than 100 meters and less than 100 meters.

e. The major reason for the difference in figures derived from the dispersion scale and those from the probability table is that linear interpolation is used with the dispersion scale when the conversion of a distance to probable errors results in a fractional value. The assumption that the distribution of bursts is uniform within the limits of 1 probable error is false.

2-41. Most Probable Position of the Mean Point of Impact

Thus far, only the probability of an outcome of a future event has been considered. This is not always the problem. For example, the observer's spottings in the fire-for-effect phase of a registration are the outcome of the rounds fired, but they do not in themselves define the relative locations of the mean point of impact and target which yielded these spottings. The problem is to find the most probable relative locations.

a. There are simple methods of determining the most probable location of the target with respect to the mean point of impact. These methods are based on, first, the fact that the definite range spottings used are of two outcomes only—either over or short—and, second, the assumption that the small number of rounds observed follows normal distribution exactly.

b. For example, if five shorts and one over are obtained, five-sixths, or 83.33 percent, of the rounds fell short of the target; according to the dispersion scale, the target must be 1.52 probable errors beyond the mean point of impact ($1 PE + \frac{8.33}{16} PE$, or $1.52 PE$, beyond the mean point of impact). By definition, 50 percent of the rounds fell short of the mean point of impact; therefore,

33.33 (83.33—50.00) percent of the rounds fell between the mean point of impact and the target. In the probability tables, 0.3333 represents 1.43 probable errors, to the nearest hundredth, which is a more accurate estimate of the distance of the target from the mean point of impact. Use of the preponderance formula described in chapter 19 indicates the target to be 1.33 probable errors beyond the mean point of impact

$$\left(\frac{5 \text{ shorts} - 1 \text{ over}}{2 \times 6} \right) \times \text{fork} = \frac{1}{3} \text{ fork} = 1.33 PE.$$

Probability tables provide the most accurate answer; however, the preponderance formula is used because of its simplicity and because the small number of rounds considered (6) does not warrant striving for the extra theoretical precision of the probability table.

2-42. Single Shot Hit Probability and Assurance

Single shot hit probability (SSHP) is the probability of hitting a target or area of finite dimensions with any one round.

a. The probability of a round hitting in any one of the areas bounded by 1 range probable error (PE_r) and 1 deflection probable error (PE_d) is the product of the probability of not exceeding that range error and the probability of not exceeding that deflection error. This basic principle is applied in computing the single shot hit probability. Before the probability tables can be used, the specified error must be reduced to equivalent probable errors.

b. Computation of single shot hit probability is based on the assumption that the mean point of impact is adjusted to the exact center of the target or area. This means, for example, that the limit of error is 20 meters if the target is 40 meters deep (fig. 2-22). The same principle is true for deflection. Therefore, in order to reduce target dimensions to equivalent probable errors, it is first necessary to determine the limit of error for range (i.e., one-half that target dimension parallel to the GT line) and for deflection (i.e., one-half that target dimension perpendicular to the GT line). Then, the limits of error are divided by the respective firing table probable errors for the weapon, charge, and range being used. The quotient (t) is the limit of the error expressed in probable errors and is the argument for entering the probability tables to

determine the range probability and the deflection probability. The product of these two probabilities gives the probability of hitting a specific quarter of the four quarters of the target as shown by the shaded area in figure 2-22. Since a hit in any one of the four quarters constitutes success, the probability of getting a hit in any quarter must be multiplied by 4.

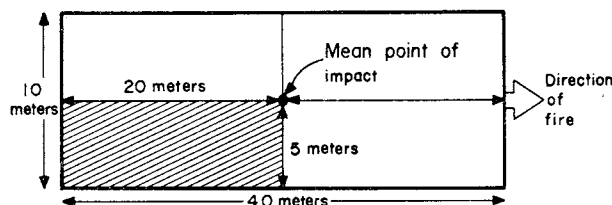


Figure 2-22. Single shot hit probability.

c. For example, the target is a bridge 10 meters by 40 meters with the long axis parallel to the direction of fire. Range to target is 9,870 meters. The mean point of impact is adjusted on the center of the target by use of precision fire techniques. After the mean point of impact is correctly adjusted on the center of the target, the single shot hit probability is computed as follows:

Given: A 155-mm howitzer M109 firing charge 7 at a range of 9,870 meters.

From the firing table, determine PE_r and PE_d . Enter table G with range rounded to the nearest 100 meters (9900). $PE_r = 27$ meters;

$$PE_d = 4 \text{ meters.}$$

$$\text{Range } t = \frac{\frac{1}{2}(40)}{27} = \frac{20}{27} = 0.74.$$

$$\text{Deflection } t = \frac{\frac{1}{2}(10)}{4} = \frac{5}{4} = 1.25.$$

From probability tables: $t(0.74) = 0.1911$;
 $t(1.25) = 0.3003$.

$$SSHP = 4(0.1911)(0.3003) = 0.2295 = 22.95 \text{ percent.}$$

Angle of bias between—	Effective depth	Effective width
0 and 400 mils.....	Actual length.....	Actual width.
401 and 650 mils.....	$2 \times$ actual width.....	$0.5 \times$ actual length.
651 and 950 mils.....	$1.41 \times$ actual width.....	$0.71 \times$ actual length.
951 and 1,200 mils.....	$1.15 \times$ actual width.....	$0.87 \times$ actual length.
1,201 and 1,600 mils.....	Actual width.....	Actual length.

2-43. Single Shot Hit Probability for Bias Targets

a. A target is said to be biased when its specified dimensions are neither parallel nor at right angles to the direction of fire. The only change in procedure required is that the specified dimensions of the target must first be converted to an effective depth and width which fits the dispersion pattern with respect to the GT line. Once the effective depth and width are known, the single shot hit probability is computed as discussed in paragraph 2-42. Figure 2-23 illustrates a bias target.

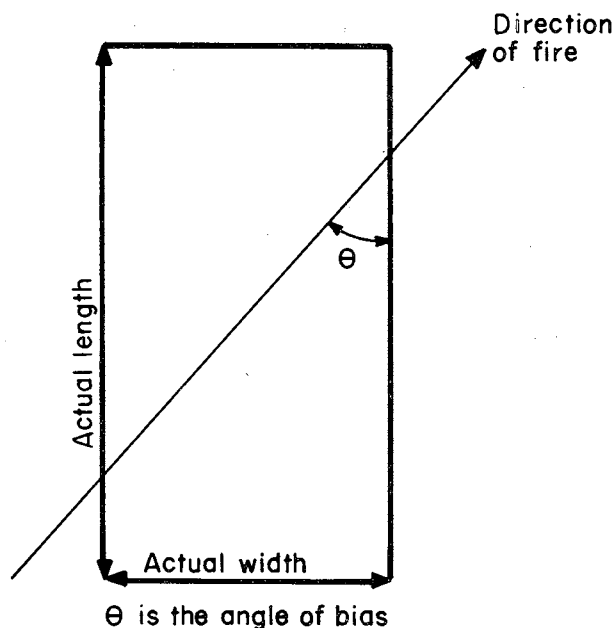


Figure 2-23. Bias target.

b. The following tabulation can be used to approximate the effective dimensions. Greater accuracy is not warranted in view of the approximate dimensions of the target itself and the approximation of the angle of bias. The angle of bias is the smallest angle measured between the long axis of the target and the direction of fire.

c. For example, the target is a bridge 8 meters by 40 meters with the long axis at an 800-mil angle to the direction of fire. The range is 11,040 meters. After the mean point of impact has been adjusted to the center of the target, the single shot hit probability for a 155-mm howitzer M109 firing charge 7 is computed as follows:

Effective depth = 1.41 (from *b* above) $\times$ 8 meters = 11.28 (use 11).

Range $t = \frac{1/2(11)}{29} = \frac{11}{58} = 0.19$.

Effective width = 0.71 (from *b* above) $\times$ 40 meters = 28.40 (use 28).

Deflection $t = \frac{1/2(28)}{4} = 3.50$.

From probability tables: $t(0.19) = 0.0511$;
 $t(3.50) = 0.4908$.

SSHP = $4(0.0511)(0.4908) = 0.1003$, or 10.03 percent.

2-44. Conversion of a Circular Target to an Equivalent Square

a. Many targets are described as circular. In order to compute single shot hit probability for a circular target, it is necessary to convert the target to a square of the same area. This conversion is necessary because the dispersion pattern of cannons is elliptical and can be reasonably defined by a rectangle.

b. A circular shape is converted to a square shape by multiplying the radius of the circle by 1.7725 (1.7725 is the square root of π). The product is the length of a side of a square which has an area equal to the area of the original circle.

2-45. Assurance and Assurance Graphs

Assurance is a broad term associated with the probability of hitting a target with any given number of rounds, assuming a constant single shot hit probability.

a. The assurance formulas for at least one hit, two hits, three hits, etc., may be graphed as shown in figures 2-24 through 2-26. The only computation necessary is that for the single shot hit probability. Once that is known, the graph provides a rapid determination of either the assurance obtainable from firing a specified number of rounds (*N*) or the number of rounds required for a desired assurance.

b. The number of rounds is indicated along the bottom of the graph, the single shot hit probability is indicated on either side of the graph, and the assurance is indicated by the curves drawn within the graph. When the assurance graph is used, the intersection of the two known elements is found and then the desired element is read opposite this intersection. Interpolation between numbered graduations is permissible.

c. For example, determine the assurance of getting at least one hit when 20 rounds are fired with a single shot hit probability of 0.045. (Answer: 0.60, fig. 2-24.) Determine the number of rounds required for at least two hits when the single shot hit probability is 0.08 and the desired assurance is 0.70. (Answer: 30 rounds, fig. 2-25.)

d. Although it is impossible to be certain of the number of rounds needed to hit or destroy a target, use of the graphs will provide an approximation. Probability (assurance) is a substitute for fact, and, until the fact is actually known, probability provides the best guide as to what to expect. Unfortunately, the single shot hit probability and assurance levels are usually less than the ones derived from the method in *a* through *c* above, because the mean point of impact usually is not at the center of the target as assumed. For example, an apparent mean point of impact located by the mean of 12 rounds is more accurate than one located by the mean of only 6 rounds. An estimate of the probable error of the mean point of impact as a function of the number of rounds from which it was determined can be found by multiplying the firing table probable error by the appropriate factor shown below.

Number of rounds	Factor	Number of rounds	Factor
2-----	0.7	12-----	0.3
4-----	.5	14-----	.3
6-----	.4	16-----	.3
8-----	.4	18-----	.2
10-----	.3	20-----	.2

e. In the example shown in paragraph 2-42c for the 155-mm howitzer, if the adjusted data of the mean point of impact were based on six rounds, then the range probable error of the mean point of impact at that time would be 11 meters ($0.40 \times 27 = 10.80$). This has the effect in SSHP computations of an apparent increase in the weapon probable error. The magnitude of the apparent weapon probable error is approximately

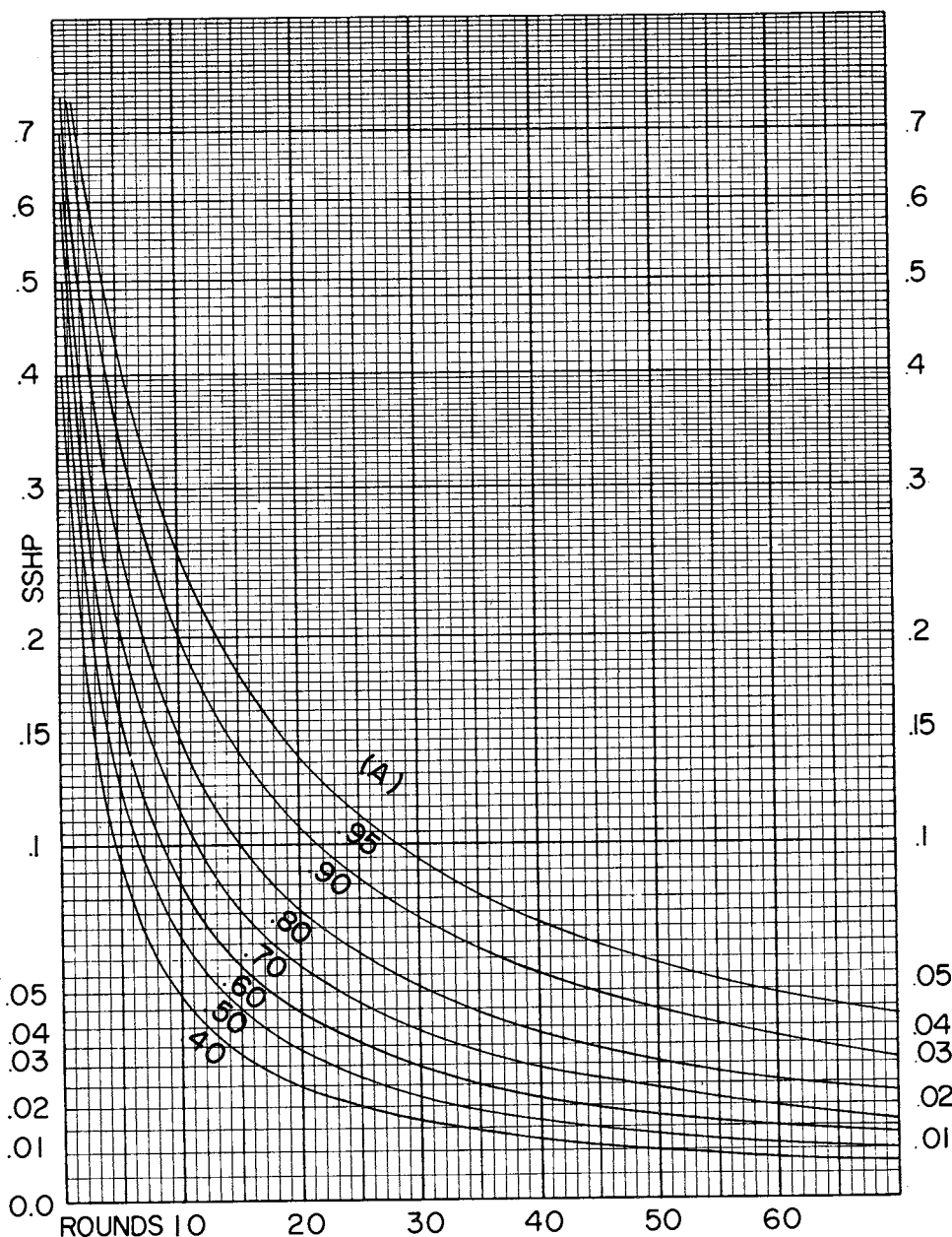


Figure 2-24. Assurance of at least one hit for "N" rounds when single shot hit probability is known.

equal to the square root of the sum of the squares of the weapon probable error and the mean point of impact probable error or, in this case, $(27)^2 + (11)^2$, equals 29 meters to the nearest meter. Hence, 29 meters would be used in the place of 27 meters in the computation of single shot hit probability. If the target is to be attacked without adjustment, the apparent weapon probable error is assumed to be twice the weapon probable error. The deflection

probable error can be found in a similar manner although the change normally will not be significant. The method outlined above is valid for only one round in fire for effect. Thus, it is not to be used with the assurance graphs.

2-46. Developed Probable Error

Firing tables indicate the probable errors of a cannon in various dimensions (range, deflection,

height of burst, and time to burst). The use of round-to-round data from mean-point-of-impact registrations and fall-of-shot calibrations will provide a positive check on the performance of cannons and crews. The developed probable error can be approximated by multiplying the maximum dispersion observed (longest range minus shortest range) in a group of rounds by the appropriate factor from the following tabulations (n is the number of rounds in the group).

n	Factor	n	Factor
2	0.60	8	0.24
3	.39	9	.23
4	.33	10	.22
5	.29	11	.21
6	.27	12	.21
7	.25		

For example; the maximum observed range dispersion in a group of eight rounds is 150 meters. The approximate developed range probable error is 36 meters to the nearest meter ($0.24 \times 150 = 36.0$).

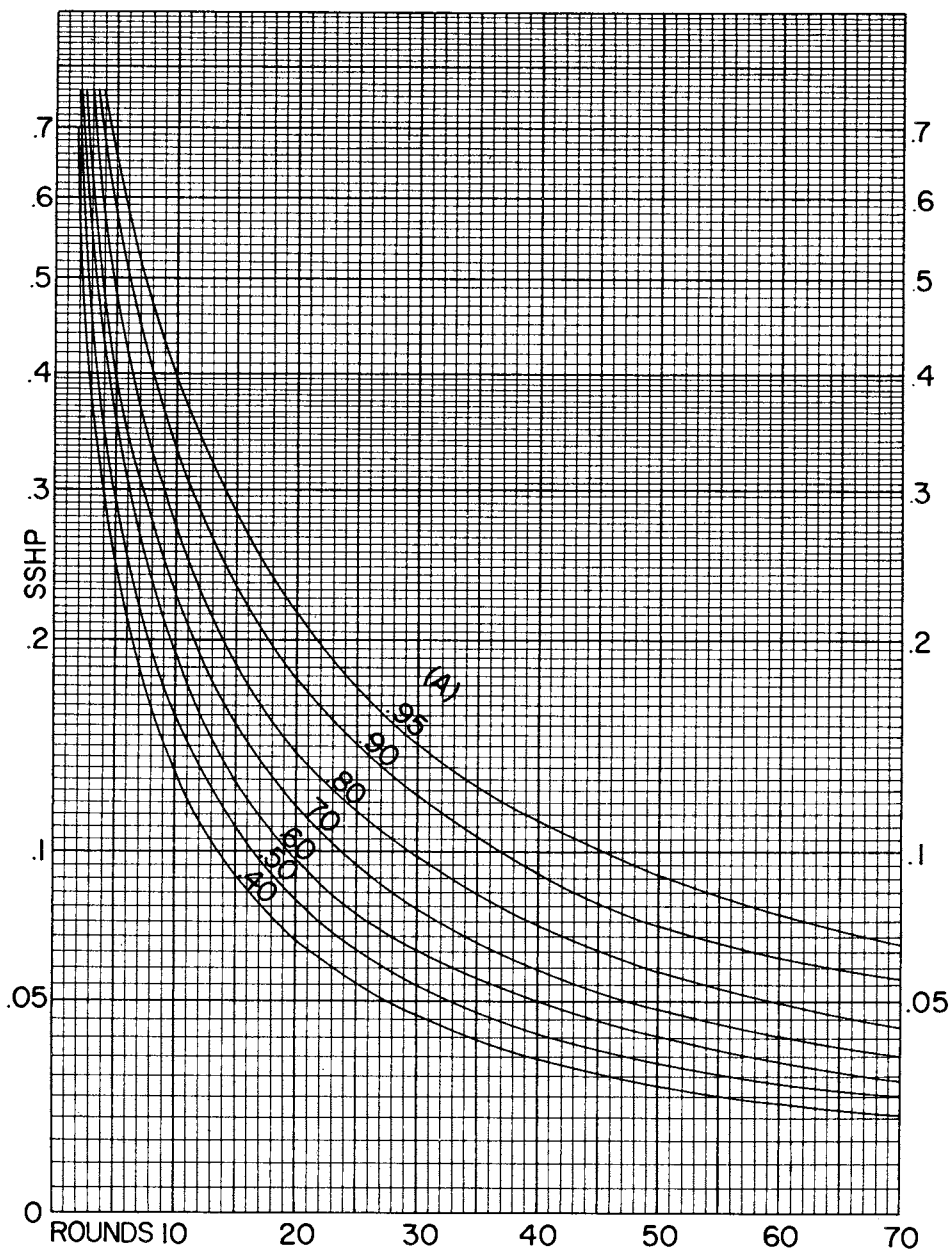


Figure 2-25. Assurance of at least two hits for "N" rounds when single shot hit probability is known.

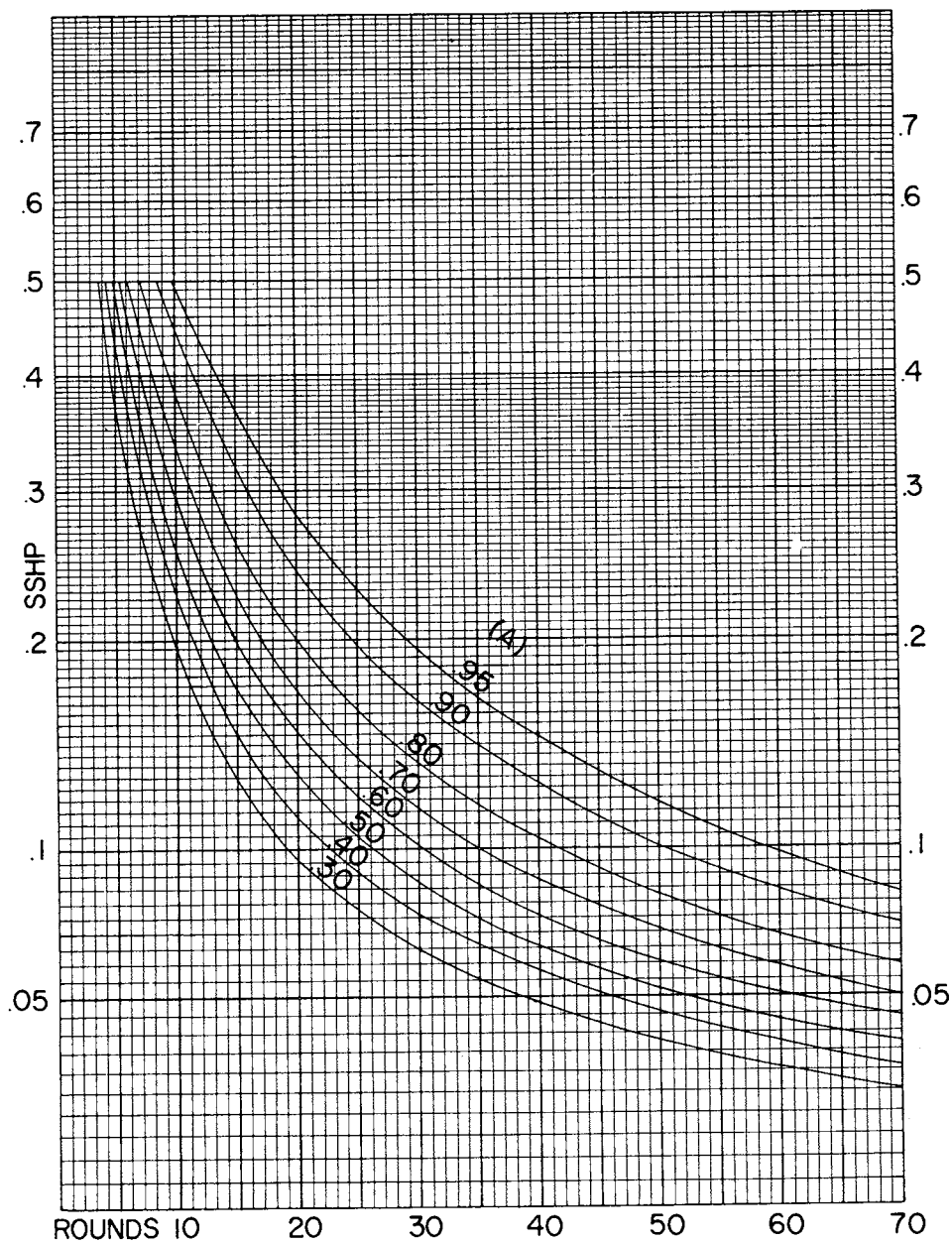


Figure 2-26. Assurance of at least three hits for "N" rounds when single shot probability is known.

PART TWO

FIRING BATTERY

CHAPTER 3

FIRING BATTERY, GENERAL

3-1. Introduction

The firing battery is that component of the gunnery team that executes the fire commands generated at the fire direction center. The firing battery consists of the firing battery headquarters, the howitzer (gun) sections, and, in some units, an ammunition section. Battery fire direction personnel are assigned to the firing battery headquarters and maintain the charts necessary for the processing of fire missions. Fire direction procedures are discussed in part four.

3-2. Map and Azimuth Terms

The map and azimuth terms (fig. 3-1) used in the firing battery are defined in *a* through *i* below.

a. Grid Line. A grid line is a line extending north and south or east and west on a map, photomap, or grid sheet. Grid lines are parallel and perpendicular to the central meridian of the grid zone in question. The parallel lines are, normally 1,000 meters apart and are used to measure coordinates.

b. Magnetic North. Magnetic north is the direction to the magnetic North Pole.

c. True North. True north is the direction to the geographic North Pole.

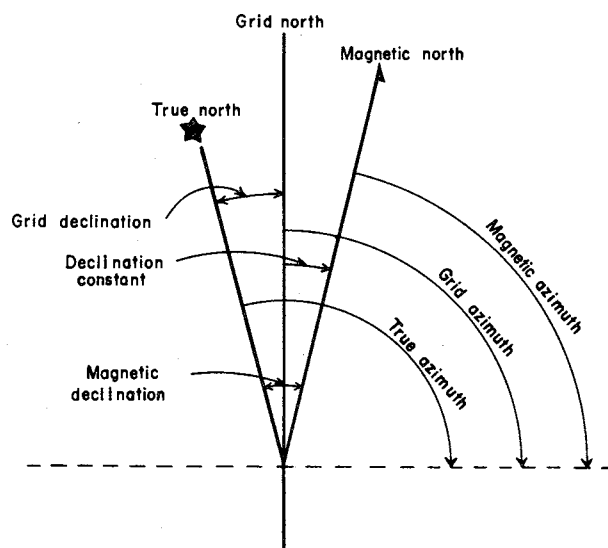
d. Grid North. Grid north is the north direction of the vertical grid lines on a military map, photo-map, or grid sheet.

e. Azimuth. Azimuth is a direction expressed as a horizontal, clockwise angle measured from north. This angle may be a—

(1) *Magnetic azimuth*, measured from magnetic north.

(2) *True azimuth*, measured from true north.

(3) *Grid azimuth*, measured from grid north. (Grid azimuth is the azimuth normally employed in the field artillery. The artilleryman uses the term “azimuth” and “direction” synonymously to indicate grid azimuth. The command to the executive officer to indicate the grid azimuth of the direction of fire is **AZIMUTH** (so much). The command of the forward observer to indicate the grid azimuth to his adjusting point is **DIRECTION** (so much).)



★Figure 3-1. Map and azimuth terms.

f. Back-Azimuth. A back-azimuth is the reverse direction of an azimuth. The back-azimuth is equal to the azimuth plus or minus 3,200 mils, whichever gives a result between 0 and 6,400 mils.

g. Declination Constant. Declination constant (fig. 3-1) is the horizontal, clockwise angle from grid north to magnetic north; in

other words, the grid azimuth of magnetic north. The declination constant is recorded for each instrument equipped with a magnetic needle. The constant for any instrument may vary in different localities; the constants of different instruments in the same locality also may vary.

h. Magnetic Declination. Magnetic declination (fig. 3-1) is the smaller angle between true north and magnetic north. This angle is indicated in the marginal data of maps as east or west of true north. Since the magnetic declination varies slightly from year to year, a correction factor (the annual magnetic change) also is shown in the marginal data of military maps.

i. Grid Declination. Grid declination (fig. 3-1) is the smaller angle between true north and grid north. Grid declination is indicated in the marginal data of maps as east or west of true north.

3-3. Artillery Firing Battery Terms

a. Aiming Point. An aiming point is a sharply defined point that is used as a reference in laying an artillery piece for direction. There are two general types of aiming points—distant aiming points and close-in aiming points.

★(1) *Distant aiming point.* A distant aiming point may be used as a reference in laying for direction or as a means of boresighting artillery weapons. When a distant aiming point is used, it should be at least 1,500 meters from the position area so that normal displacement of the panoramic telescope due to firing or traverse will not cause an error of more than one-half mil in direction. If greater accuracy is desired, a greater distance must be used. Advantages of using a distant aiming point are that it may be used immediately upon occupation of a position or as an alternate aiming point in the event the close-in aiming point is rendered useless. Disadvantages of using a distant aiming point are that it may be obscured by darkness, dust, fog, or smoke; illumination is not practicable; and the pieces are not parallel when laid with a common deflection to the distant aiming point (para 4-7a(2)).

(2) *Close-in aiming point.* There are two types of close-in aiming points.

(a) *Infinity collimator.* The infinity collimator normally is used as the primary aiming point for each piece. The collimator is an optical instrument which simulates an aiming point at infinity. The collimator can be emplaced 4 to 15 meters from the weapon, and it permits application of corrections for weapon displacement.

(b) *Aiming posts.* Two aiming posts (striped rods) may be used instead of the collimator as the primary aiming point for each piece. The aiming posts are placed so that the two aiming posts and the panoramic telescope form a straight line and so that the near aiming post is halfway between the panoramic telescope and the far aiming post.

b. Alternate Aiming Point. An alternate aiming point is one that is used when the primary aiming point is rendered useless. It can be either a distant aiming point or a close-in aiming point. When a 6,400-mil capability is required, at least two aiming points must be used because at certain angles of elevation the primary aiming point will be masked by the tube or, in the case of certain self-propelled weapons, by the commander's cupola. For towed weapons, normally two close-in aiming points 3,200 mils apart are used.

c. Battery Center. The battery center is a point materialized on the ground at the geometric center of the howitzer (gun) sections. It is the point which is plotted on the firing charts to represent the location of the battery.

d. Base Piece. The base piece normally is the piece with the shooting strength closest to the average shooting strength of the battery. It is placed on or near the battery center and normally is used for registrations.

e. Orienting Line. An orienting line is a line of known direction established on the ground near the firing battery which serves as a basis for laying for direction. The azimuth of the orienting line is stated as the direction from the orienting station to a designated end of the orienting line. The end of the orienting line may be marked by any sharply defined point, such as a steeple, flagpole, or stake.

f. Orienting Station. An orienting station is a point established on the orienting line; near the gun position from which the battery may be oriented.

g. Orienting Angle. An orienting angle is the horizontal, clockwise angle from the line of fire to the orienting line.

h. Reference Point. A reference point is a prominent and easily located point on the terrain and is used for orientation.

★*i. Deflection.* Deflection is the horizontal, clockwise angle measured from the line of fire, or the rearward extension of the line of fire, to the line of sight to a designated aiming point, with the vertex at the instrument.

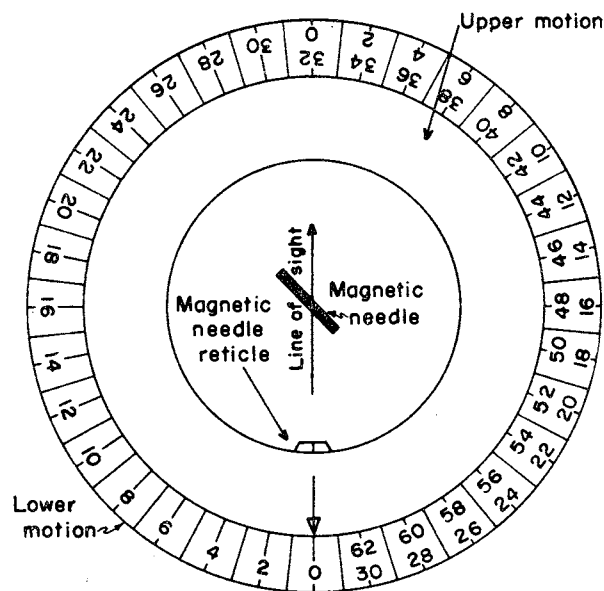
j. Refer. To refer is to measure the deflection to a given point without moving the orientation (0-3200) line of the instrument. The command REFER means to measure and to report the deflection. If it is desired to record this deflection, the command is RECORD REFERRED DEFLECTION.

k. Indirect Laying. Indirect laying is the aiming of a piece by sighting at an aiming point. The piece is laid for direction by setting a given deflection on the sight and traversing the tube until the line of sight of the panoramic telescope is on the aiming point and by leveling the appropriate bubbles. The piece is laid for elevation by setting the quadrant elevation on the range quadrant or gunner's quadrant and elevating or depressing the tube until the appropriate bubble is level.

l. Direct Laying. Direct laying is the aiming of a piece by sighting directly on the target.

3-4. Aiming Circle

a. The aiming circle is an instrument for measuring horizontal and vertical angles. It is the instrument usually used to lay the battery. The head of the instrument has two motions, called the lower (nonrecording) motion and the upper (recording) motion. On the lower motion, which may be locked in any desired position, is an azimuth scale (fig 3-2), graduated every 100 mils and numbered every 200 mils. The scale is numbered from 0 to 62 (6200); the upper half of the scale, numbered 32 to 62 (3200 to 6200), has a second scale numbered in red from 0 to 30 (0 to 3000). The upper motion



★Figure 3-2. Schematic drawing of aiming circle.

has an index (for the azimuth scale on the lower motion), an azimuth micrometer (graduated in mils from 0 to 100), a magnetic needle, a reticle used in centering the magnetic needle, and a telescope. The reticle for centering the needle is located directly below the axis of the telescope. When the needle is centered in the reticle, the line of sight of the telescope is in the direction in which the needle is pointing. When the upper motion is moved with respect to the lower motion, the horizontal, clockwise angle from the 0-3200 line of the lower motion to the line of sight of the telescope can be determined by combining the values read opposite the appropriate indexes on the azimuth scale and the azimuth micrometer.

b. When the magnetic compass of the aiming circle is being used, all objects (heavets, small arms, etc,) which may attract the needle must be kept away from the instrument. The aiming circle should be set up no closer to the following objects than the distances listed.

	Meters
High-tension powerlines	150
Railroad track	75
Medium and heavy towed artillery pieces and all self-propelled artillery pieces	60
Light towed artillery pieces, telegraph wire, and vehicles	40
Barbed wire and small metal objects	10

3-5. Panoramic Telescope

The panoramic telescope (sometimes called the sight) is mounted on the piece and measures horizontal, clockwise angles in mils.

CHAPTER 4

FIRING BATTERY PROCEDURES

Section I. LAYING THE BATTERY

4-1. General

a. When a battery occupies a position, the tubes of the pieces must be pointed in a known direction. The known direction should be the direction toward the center of the assigned zone of fire. The direction in which to lay the battery may be furnished to the battery executive officer, or he may estimate the direction based on his knowledge of the situation.

b. Normally, the battery is laid by following two steps:

- (1) Establish the 0-3200 line of the aiming circle parallel to the direction of fire.
- (2) Lay the howitzer (gun) tubes parallel to the 0-3200 line of the aiming circle (reciprocal laying (para 4-3)).

c. In rare cases, it may be necessary or desirable to lay the battery without using an aiming circle (para 4-7).

4-2. Orienting the Aiming Circle

There are several methods that can be used to orient the 0-3200 line of the aiming circle in the direction of fire, but the three methods described in *a* through *c* below (azimuth, orienting angle, and aiming point and deflection) are the ones used most often. All three methods are similar in that a deflection (the horizontal, clockwise angle from direction of fire to an aiming point) is determined and set on the aiming circle, and the lower motion of the aiming circle is then used to sight on the aiming point.

a. *Orienting by Grid Azimuth.* Magnetic north is used as the aiming point in orienting by grid azimuth. To orient the 0-3200 line of the aiming circle on a grid azimuth, it is necessary to determine the deflection from that azimuth to magnetic north, set that deflection on the aiming circle with the upper motion, and sight on magnetic north by centering (with the lower motion) the magnetic needle. The instrument reading to set on the aiming circle is computed by subtracting the grid

azimuth from the declination constant of the instrument (adding 6400 to the declination constant, if necessary).

Example: The executive officer receives the command LAY ON AZIMUTH 5250. The declination constant of the aiming circle is 200 mils.

Solution:

Declination constant-----	200 mils
	+6,400 mils
	6,600 mils
Minus the grid azimuth-----	5,250 mils
Instrument reading to set on the aiming circle-----	1,350 mils

After setting up the aiming circle at a point away from all magnetic attractions and so that it is visible to all pieces (if possible), 1350 is set on the aiming circle with the upper motion. The magnetic needle is centered with the lower motion without disturbing the setting of 1350. The 0-3200 line of the aiming circle is now oriented on azimuth 5250 (fig. 4-1).

b. *Orienting by Orienting Angle.* An orienting line must be established to lay the battery by orienting angle. The orienting line is established on the ground by a stake over which the aiming circle is to be set up (orienting station) and a distant point which may be a stake or a terrain feature (end of orienting line). The orienting angle is the horizontal, clockwise angle from the direction of fire to the orienting line. The executive officer normally is given the orienting angle; but, if he knows the azimuth of the orienting line and the azimuth of the line of fire, he can compute the orienting angle by subtracting the azimuth of fire from the azimuth of the orienting line. The upper motion is used to set the orienting angle on the aiming circle, and the lower motion is used to sight the aiming circle on the end of the orienting line. The 0-3200 line is now established parallel to the line of fire.

Example: The azimuth of the orienting line is 1,300 mils. The azimuth on which the executive

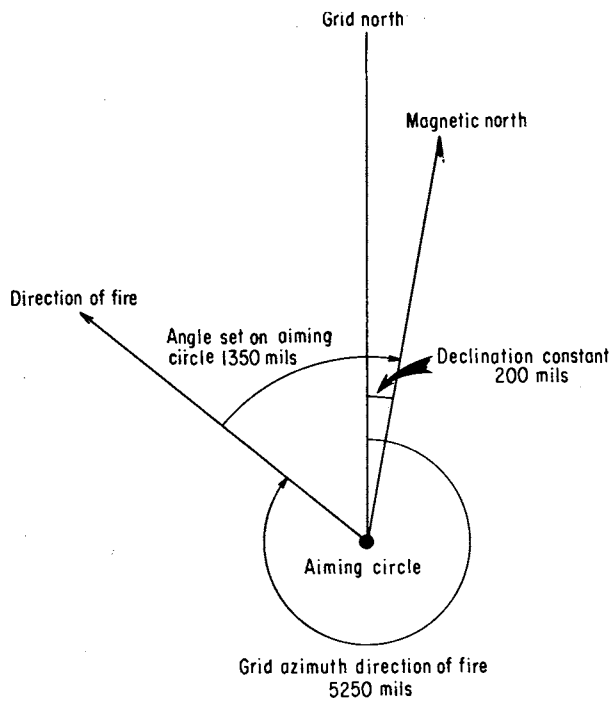


Figure 4-1. Orienting by grid azimuth

officer wishes to lay is 2,500 mils. The orienting angle is 5,200 mils ($1300 + 6400 = 7700 - 2500 = 5200$).

The aiming circle is set up over the orienting station. The upper motion is used to set off 5,200 mils on the aiming circle. The executive officer then sights on the end of the orienting line, using the lower motion. The 0-3200 line of the aiming circle is now oriented (fig. 4-2).

c. Orienting by Aiming Point and Deflection. In some cases, when a battery is occupying a position, the executive officer is given an aiming point and deflection on which to lay. To orient the aiming circle, the executive officer merely sets off the deflection, using the upper motion, and sights on the aiming point, using the lower motion. The 0-3200 line of the aiming circle is then parallel to the direction of fire.

4-3. Reciprocal Laying

a. General. Reciprocal laying is a procedure by which the 0-3200 line of one instrument (aiming circle) and the 0-3200 line of another instrument (panoramic telescope) are laid parallel. When the 0-3200 lines of an aiming circle and a panoramic telescope are parallel and the piece has been properly boresighted, the tube of the piece is parallel to both 0-3200 lines. The principle of reciprocal

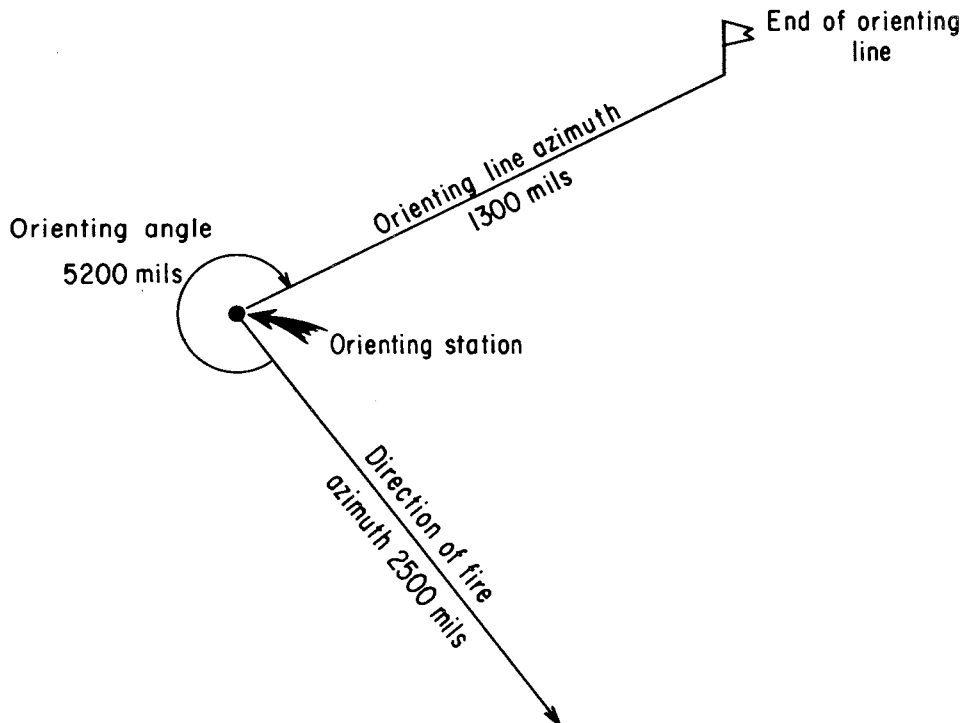
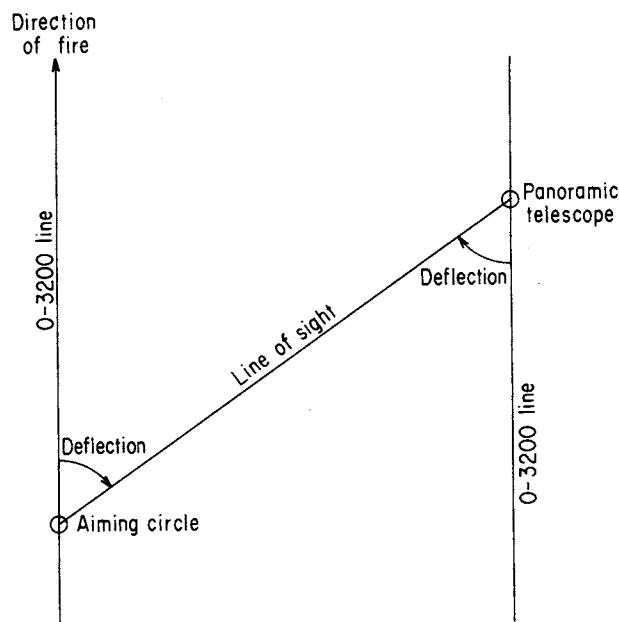


Figure 4-2. Orienting by orienting angle.

laying is based on the geometric theorem, which states that if two parallel lines are cut by a transversal the alternate interior angles are equal. The parallel lines are the 0-3200 lines of the instruments; the transversal is the line of sight between the two instruments. The alternate interior angles are the equal deflections placed on the instruments (fig. 4-3).



★Figure 4-3. Principle of reciprocal laying.

b. *Procedure.* After the 0-3200 line of the aiming circle has been established parallel to the direction of fire (para 4-2), the instrument operator, using the upper motion, sights on the objective lens of the panoramic telescope, reads the deflection on the azimuth and azimuth micrometer scales, and announces the deflection to the gunner on the piece. The gunner sets off the announced deflection on the panoramic telescope and causes the piece to be moved until the telescope is sighted on the objective lens of the aiming circle. Because the panoramic telescope is offset laterally from the axis about which the carriage is moved, the telescope is displaced horizontally. When the telescope has been sighted on the aiming circle, the gunner reports READY FOR RECHECK and the instrument operator again sights on

the objective lens of the telescope and reads and announces the deflection. This procedure is repeated until the gunner reports a difference of zero mils between successive deflections. The piece has then been laid.

Example: The following commands and procedures are used in reciprocal laying:

(1) *Executive officer*—BATTERY ADJUST, AIMING POINT THIS INSTRUMENT.

(2) *Gunner of number 3*—NUMBER 3, AIMING POINT IDENTIFIED. (All gunners report in this manner. For brevity, only the commands of number 3 will be shown here. Other pieces are laid in the same manner.)

(3) *Executive officer*—NUMBER 3, DEFLECTION 3091. (The executive officer had referred the aiming circle to the objective lens of the telescope.)

(4) *Gunner of number 3*—NUMBER 3, DEFLECTION 3091. (The gunner sets off 3091 on his telescope and causes the piece to be shifted until he is sighted through the telescope within 10 mils. In the meantime, the executive officer is laying other pieces.) When the gunner of number 3 piece has completed his laying with deflection 3091, he announces NUMBER 3 READY FOR RECHECK.

(5) *Executive officer*—NUMBER 3, DEFLECTION 3093.

(6) *Gunner of number 3*—NUMBER 3, DEFLECTION 3093, 2 MILS. (This indicates a 2-mil difference between this deflection and the previous deflection.) After setting off 3093 and traversing the piece until the telescope is again sighted on the aiming circle, the gunner announces NUMBER 3 READY FOR RECHECK. The executive officer continues to lay the same piece once it is within 3 mils of the announced deflection.

(7) *Executive Officer*—NUMBER 3, DEFLECTION 3093.

(8) *Gunner of number 3*—NUMBER 3, DEFLECTION 3093. ZERO MILS.

(9) *Executive officer*—NUMBER 3 IS LAID. (Unit standing operating procedure will specify the deflection at which aiming posts or collimator will be placed upon completion of laying.)

4-4. Recording Laying for Direction

a. Under normal circumstances, after the battery has been laid parallel, the executive officer will cause each piece to refer to a common deflection and the crew to set out the collimator or aiming posts along the resulting line of sight (the tube is not moved). If this procedure is followed, each piece will have an aiming point and a deflection which, when used, will cause the tube to be pointed in the direction in which it was initially laid without again going through the process of reciprocal laying. Furthermore, the direction in which the battery is initially laid and the corresponding deflection are used as references from which the fire direction center (FDC) can derive firing deflections for future targets.

b. The collimator is placed 4 to 15 meters from the sight of the weapon. (Best results are obtained from 5 to 12 meters). If aiming posts are used, it is desirable to have the far aiming post at least 100 meters from the piece. The near aiming post must be placed at one-half the distance from the piece to the far aiming post.

★c. The referred deflections at which to place the collimator or aiming posts that have been found to be most convenient are shown below:

Weapon	Deflections
105-mm (M101A1) -----	2800
105-mm (M102) -----	600
105-mm (M108) -----	2600
155-mm (M114A1) -----	2400
155-mm (M44) -----	600
155-mm (M109) -----	2600
8-inch (M110, M115) -----	2400
175-mm gun (M107) -----	2400

d. If the close-in aiming point of an individual piece cannot be placed at the announced common deflection because of ground contour, foliage, trees, or other conditions, the gunner turns the azimuth micrometer knob until the azimuth scale is on another even 100-mil graduation. The collimator or aiming posts are aligned at this new deflection. The chief of section reports the altered deflection to the executive officer: NUMBER (so-and-so), COLLIMATOR (AIMING POSTS) AT (so many hundred), DEFLECTION (common deflection) IN LAKE (or other reason). The executive of-

ficer will then command NUMBER (so-and-so), DEFLECTION (as appropriate to the weapon) REFER. At this command, the gunner loosens the slipping azimuth scale locking screw and moves the slipping azimuth scale to the common deflection. He then tightens the locking screw and verifies the adjustment.

e. If a piece is equipped with a reset counter on the sight, the collimator or aiming posts are placed out at the referred deflection as indicated in c above, using the azimuth scale. The reset counter is then reset by pushing and turning the reset knob. The counter will automatically reset to 3200. If it is not possible to place the collimator or aiming posts on the referred deflection indicated in c above, because of ground contour, foliage, trees, or other conditions, they may be placed at any convenient deflection, using the azimuth scale. The reset counter is then reset to 3200. In either case, 3200 will then become the referred deflection for the weapon.

f. As soon as the battery has been laid parallel and referred to the close-in aiming point, the executive officer will have the gunners of all pieces refer to a distance aiming point, if one is available. For example, he may command AIMING POINT, STEEPLE, RIGHT FRONT, REFER, RECORD REFERRED DEFLECTION. Each gunner refers to the steeple and reads and reports the deflection; e.g., NUMBER 3, STEEPLE, DEFLECTION (so much). The deflection is recorded by the chief of section and the battery recorder for future use. Should the close-in aiming point of any section be rendered useless, the executive officer can maintain parallelism and control of direction by using this deflection and distant aiming point. This information is used for reemplacing the close-in aiming point at the earliest possible time.

★g. If the sight picture cannot be viewed by the gunner, the weapon should be relaid with an aiming circle. The procedure is as follows:

(1) Convert the announced deflection into an azimuth.

(2) Orient the aiming circle on the computed azimuth.

(3) Shift the weapon to the appropriate

direction of fire and lay it reciprocally on the desired azimuth.

(4) The gunner has the aiming posts or collimator realigned on the announced deflection.

Note. For the M100 series sights, the laying is done with the azimuth 6400 mil counter dial (upper window). The collimator (aiming posts) is alined using the azimuth 3200 mil counter dial (lower window). DO NOT RESET TO 3200. Using this procedure, the original deflection index on the firing chart is still valid and does not have to be displaced.

4-5. Verifying Laying For Direction

a. After the battery has been laid, the executive officer should direct checks to insure that the pieces have been laid parallel and in the proper direction.

b. Parallelism can be checked by having the gunners lay all pieces on the common deflection and then, by pairs, refer to each other's panoramic telescope. If the deflections read by the two gunners agree, the pieces are laid parallel. Each piece should check with at least two other pieces. Extreme caution must be used when checking parallelism with the M100 series sights as the reading from one sight to another will differ by 3200 mils.

c. As soon as time permits, the executive officer should make the following check:

(1) With the aiming circle (or instrument used initially to lay the battery) still set up, the executive officer commands NUMBER (so-and-so) (base piece), AIMING POINT THIS INSTRUMENT, REFER.

(2) The gunner of the piece indicated announces AIMING POINT IDENTIFIED, turns the sight of the piece until the line of sight is on the designated instrument, and announces the reading on the sight scale as NUMBER (so-and-so), DEFLECTION (so much).

(3) The executive officer sets this reading on the azimuth and the azimuth micrometer scales of his instrument with the upper motion and, with the lower motion, sights on the panoramic telescope of the piece indicated, thus establishing the 0-3200 line of his instrument parallel to the direction of fire. He now verifies the azimuth or orienting angle by one of the following procedures:

(a) If the battery was laid using the magnetic compass (by azimuth), the executive officer centers the needle, using the upper motion, and reads the azimuth and azimuth micrometer scales. This reading is subtracted from the declination constant adding 6400 mils if necessary. The result is the azimuth on which the battery is laid. If the azimuth determined is within 2 mils of the initial azimuth, the laying may be considered verified for direction.

(b) If the battery was laid on an orienting angle, the executive officer sights on the end of the orienting line, using the upper motion. If the resulting reading on the azimuth and azimuth micrometer scales agree with the initial orienting angle, the laying is considered verified for direction.

(4) The executive officer repeats the command in (1) above to each of the other pieces in turn, at the same time referring with the aiming circle to the panoramic telescope of each piece.

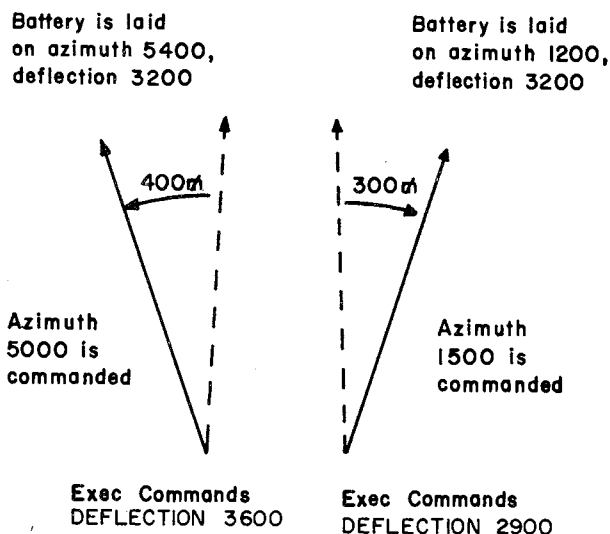
(5) If the deflection read by the gunner does not agree with that read by the executive officer, the executive officer can correct the laying of that piece for direction by giving the gunner the proper deflection.

4-6. Conversion of Data for Direction

a. *Preparation for Converting Data.* If no azimuth of fire has been given the executive officer upon occupation of position, he lays the battery parallel in a direction which appears to be most appropriate, considering his knowledge of the situation, and records a referred deflection. When a fire command prescribing a different azimuth of fire, a different method of laying, or a different azimuth of fire and a different method of laying is received, he can accomplish the change by announcing a new deflection with reference to the aiming point. In order to be prepared for any eventuality, the executive officer—

(1) Determines the azimuth on which the battery is laid.

(2) Determines the orienting angle on which the battery is laid (if an orienting line has been established).



★Figure 4-4. Shifts to compensate for difference in grid azimuth.

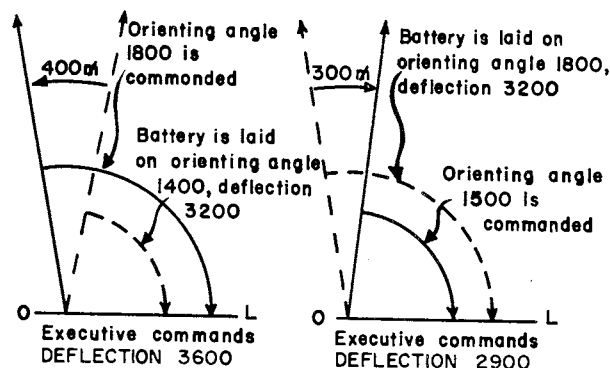
(3) Has the base piece gunner measure the deflection (refer) to visible aiming points. (He also has the gunner of another piece measure these deflections to serve as a check against large errors.)

b. Shift From One Grid Azimuth to Another. If the battery is laid on an azimuth and a command for another azimuth is received, the executive officer computes the difference between the two azimuths. He next applies this difference to the original deflection in the proper direction; an increase in grid azimuth decreases the deflection, and a decrease in grid azimuth increases the deflection (fig. 4-4). The result is the deflection necessary to lay the battery on the new grid azimuth.

c. Shift From One Orienting Angle to Another. If the battery is laid on an orienting angle and a command for another orienting angle is received, the executive officer computes the difference between the two orienting angles. He next applies this difference to the original deflection in the proper direction; an increase in orienting angle increases the deflection, and a decrease in orienting angle decreases the deflection (fig. 4-5). The result is the deflection necessary to lay the battery on the new orienting angle.

d. Shift From an Azimuth to an Orienting Angle. After the battery has been laid parallel

on an azimuth, an orienting line may be established and an orienting angle announced. This will necessitate a shift from grid azimuth to the announced orienting angle. The executive officer sets the aiming circle over the orienting station and measures the orienting angle on which the battery is laid. He compares this angle with the announced orienting angle, commands an appropriate deflection, and has the close-in aiming point realigned.



★Figure 4-5. Shifts to compensate for difference in orienting angles.

4-7. Laying the Battery Without an Aiming Circle

At times, it may be necessary to lay the battery without using an aiming circle. Among the situations that would indicate use of the methods described below are the lack of an aiming circle or the lack of time to lay by normal procedures.

a. Aiming Point and Deflection. Two methods can be used by the executive officer to lay by aiming point and deflection. The deflection on which to sight on the selected aiming point can be determined by comparing the desired direction of fire with the azimuth to the aiming point. For example, if the direction of fire is 600 mils right of the azimuth to the aiming point, the deflection would be 2600 ($3200 - 600$). If the direction of fire is 600 mils left of the azimuth to the aiming point, the deflection would be 3800 ($3200 + 600$).

★(1) The executive officer commands, to the first piece prepared for action, NUMBER (so-and-so) ADJUST, AIMING POINT (so-and-so), DEFLECTION (so much). The gunner sets the announced deflection and sights on

the aiming point by moving the tube. This action lays the tube in the desired direction. The executive officer then commands BATTERY ADJUST ON NUMBER (so-and-so), LAY PARALLEL. The gunner then lays the other pieces reciprocally with the panoramic telescope in the same manner as that used for laying with the aiming circle (para 4-3).

★(2) The executive may command BATTERY ADJUST AIMING POINT (so-and-so), DEFLECTION (so much). Each gunner sets off the announced deflection and sights on the aiming point by moving the tube. If the aiming

point is at the flank of the battery and a common deflection is given to all pieces, the battery can be considered as laid parallel. If the aiming point is to the front, the sheaf is converged at aiming point range in the target area as shown by the exaggerated diagram in example ① figure 4-6. The convergency is corrected and the sheaf is formed parallel by means of individual shifts (example ② fig. 4-6).

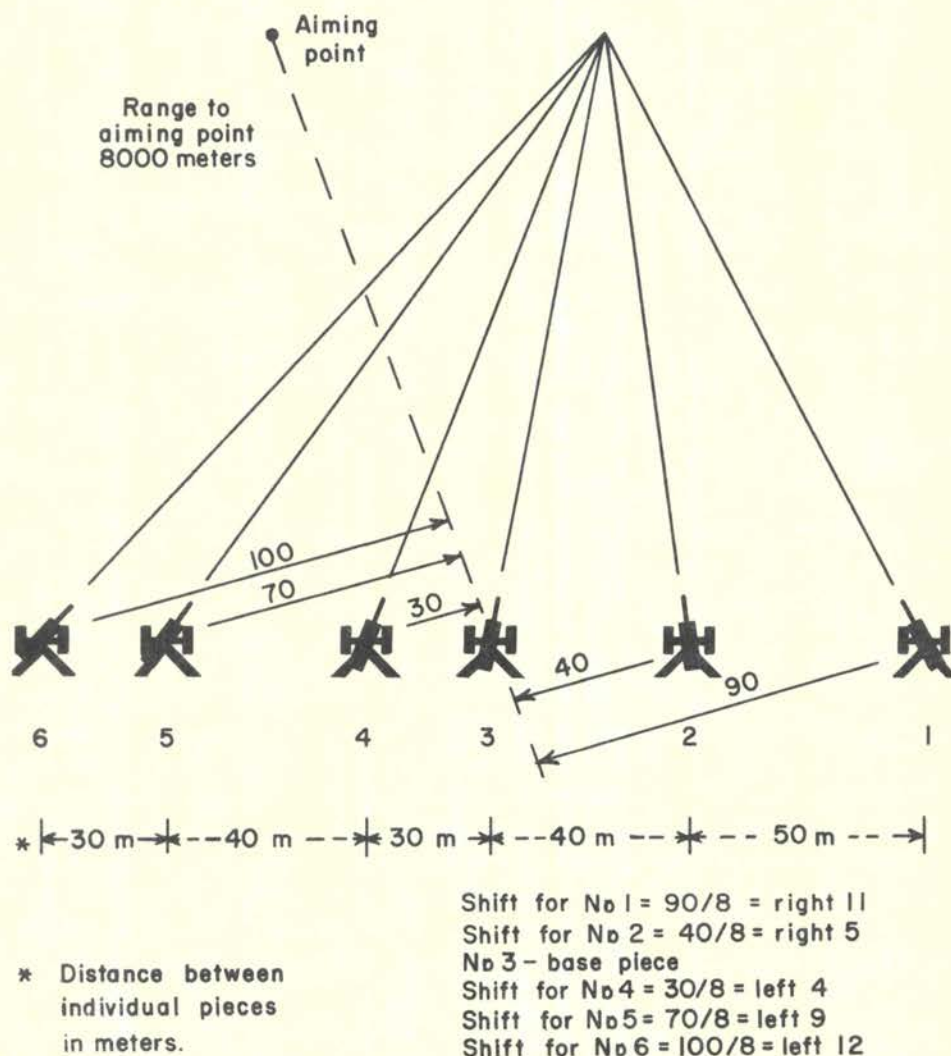
Example: It is desired to form the sheaf parallel on the number 3 piece (fig. 4-6). The shifts are

determined for each piece by using the mil relation (para 8-3b), R being the range to the aiming point and W being the perpendicular distance from the piece concerned to a line through the aiming point and number 3 piece. If the aiming point is to the rear, the sheaf will diverge. Individual shifts are computed as above to form the sheaf parallel.

b. *M2 Compass.* The command to the executive officer to lay the battery by azimuth is LAY ON AZIMUTH (so much). This command is not repeated. The executive officer places the compass on

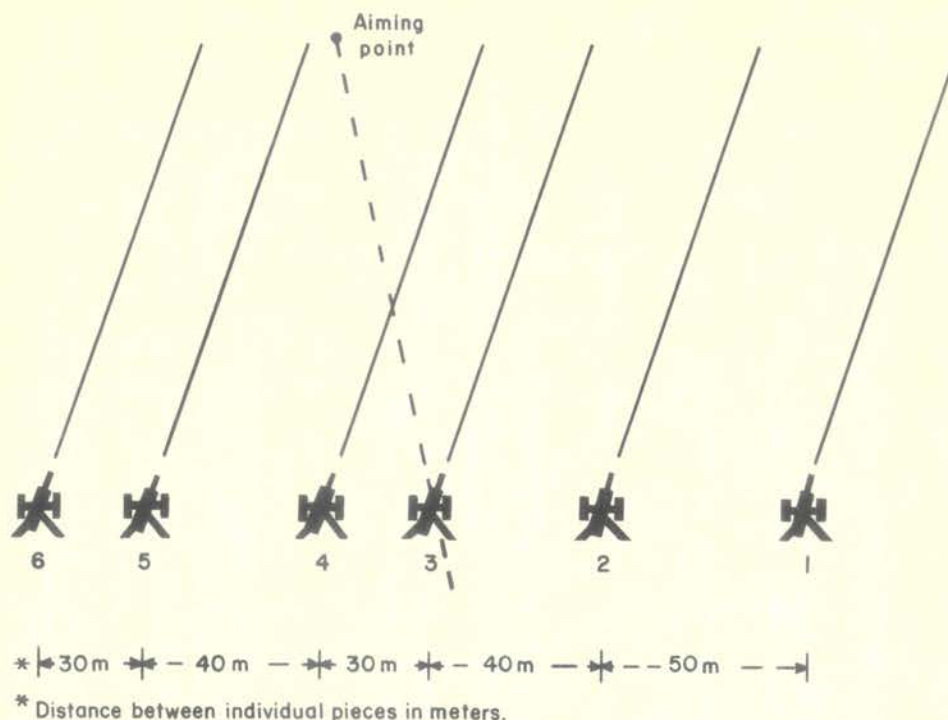
a steady object, away from objects which might affect the magnetic needle and in a place where it can be used as an aiming point for the base piece. He then—

- (1) Measures the azimuth to the telescope of the base piece.
- (2) Subtracts the announced azimuth from the azimuth which he measured (adding 6400 if necessary).
- (3) Uses the remainder (minus 3200, if necessary) as the deflection and the compass as



① Sheaf converged

Figure 4-6. Opening a converged sheaf by individual shifts to obtain a parallel sheaf



② Parallel sheaf

Figure 4-6—Continued

an aiming point to lay the base piece (fig. 4-7).

- (4) Orders the gunner of the base piece to lay the other pieces reciprocally.

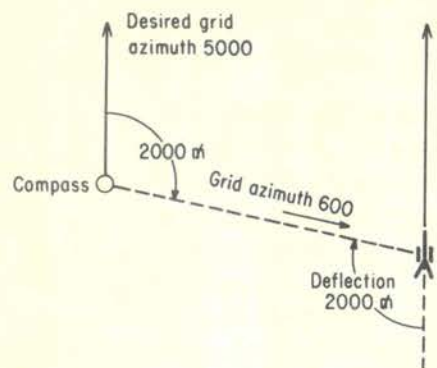
4-8. Laying by Aircraft, High Airburst, or Flare

a. No specific command is prescribed for laying the battery by sighting on an aircraft, an airburst, or a flare. The executive may lay the battery initially for direction by sighting with an instrument on the aircraft, high airburst, or flare. When no visible point is suitable for use as an aiming point, an aircraft may be employed to fly over the battery position toward, or away from, a point in the

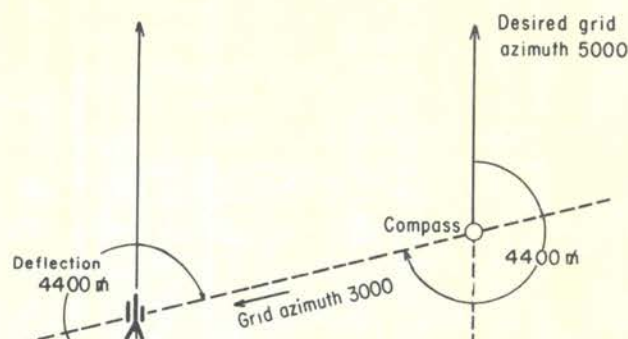
target area. The line of flight is used to establish a line of direction.

b. The high airburst or flare should be over the target area. The high airburst is fired by another unit, which has been laid previously for direction. The flare may be fired by an air or a ground observer.

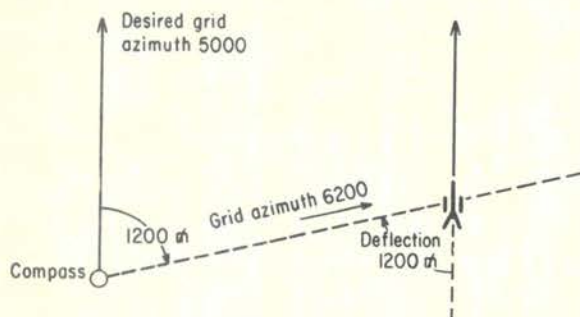
c. The executive sets up an instrument (usually in rear of the battery center) where it can be used as an aiming point by all pieces. He zeros the azimuth and micrometer scales and, by using the lower motion, places the vertical hairline on the aircraft, burst, or flare at the proper instant. Using the upper motion, the executive officer lays the pieces reciprocally.



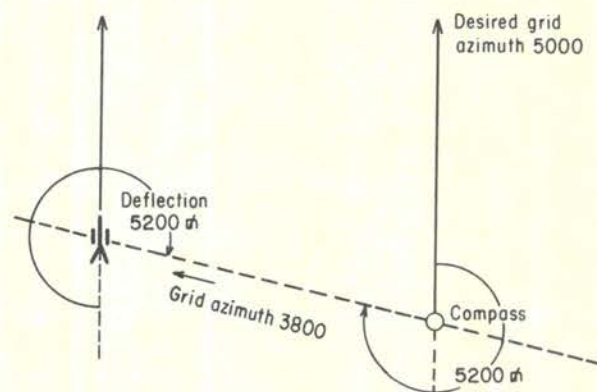
- ① Compass to left front. Deflection to lay tube parallel, 2000 mils.



- ② Compass to right front. Deflection to lay tube parallel, 4400 mils.



- ③ Compass to left rear. Deflection to lay tube parallel, 1200 mils.



- ④ Compass to right rear. Deflection to lay tube parallel, 5200 mils.

★Figure 4-7. Use of M2 compass to lay by grid azimuth

Section II. MINIMUM QUADRANT ELEVATION

4-9. Introduction

a. Safety is the responsibility of the battery executive officer within the firing battery. During training with live ammunition, a safety officer is appointed and is responsible for insuring that persons and property are not endangered by fire. In combat, the S3 or the executive officer of a separate battery is responsible for determining a quadrant elevation which will insure that rounds clear friendly troops and no-fire lines.

b. This section sets forth procedures required to clear the crest affecting trajectories from the firing battery area. The executive of-

ficer will determine and report to the FDC the minimum quadrant elevation required to clear the crest *visible from the battery position*. (For VT fuzes, the minimum quadrant elevation (QE) is computed at crest range or VT arming time range, whichever is greater.) The minimum quadrant elevation must be computed for each charge to be fired.

c. The minimum quadrant elevation required to clear the visible crest must be compared to the minimum quadrant elevation, determined by the S3 or safety officer, required to clear minimum range lines, intermediate crests, or no-fire lines. The largest minimum quadrant elevation is used.

4-10. Measuring Angle of Site to Crest

As soon as a piece is laid for direction, the chief of section determines the angle of site, as prescribed in the field manual appropriate for the weapon, to the highest crest for his piece and reports it to the executive officer.

4-11. Measuring Range to Crest

Range to the crest is determined to the nearest hundred meters by one of the following methods:

a. Obtaining Distance From a Map. The distance to a crest is determined from a map by plotting the location of the position area and determining the highest point of the crest. The distance is measured with an appropriate scale. This method is fast and accurate and is not affected by adverse terrain features as in *b* and *c* below.

b. Pacing the Distance. Pacing the distance to a crest requires no equipment; the time required to measure the range will depend on the distance and the accessibility of the route to the crest.

c. Use of the Mil Relation. Determining the range to a crest by using the mil relation is a particularly good method when the tactical situation does not permit actual measurement by one of the methods in *a* or *b* above. The mil relation method may be accomplished by the use of the panoramic telescopes of the flank pieces, by one aiming circle and one panoramic telescope, or by two aiming circles. Usually, the most practical means is the use of the panoramic telescopes of the flank pieces. For example, the battery has been laid parallel; the paced distance between flank pieces is 150 meters (fig. 4-8).

(1) The gunners of the flank pieces refer to exactly the same point on the crest.

(2) Each of the flank gunners announces the deflection to the point on the crest from his piece.

(3) The apex angle is determined from these two deflections as indicated in figure 4-8.

(4) The range in thousands of meters to the crest is determined by dividing the battery front in meters by the apex angle in mils (the mil relation).

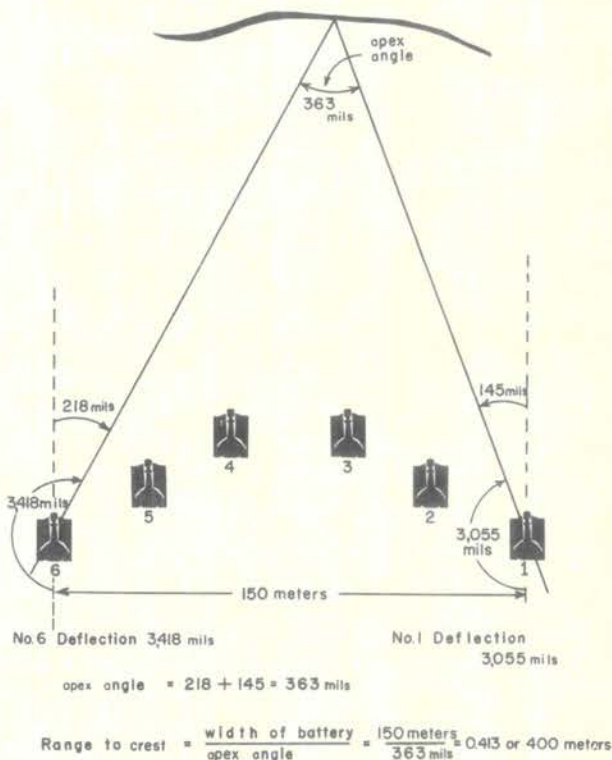
d. Estimation. If none of the methods of determining the range to the crest in *a* through *c* above is possible, the range is estimated.

4-12. Computation of Minimum Quadrant Elevation for Firing With Fuzes Other Than VT

a. Army regulations require that a projectile fired with a fuze other than VT clear friendly troops by 5 meters vertically and that the quadrant elevation computed for the point 5 meters above the friendly troops be modified by adding 2 forks.

b. Elements involved in the computation of minimum quadrant elevation (example 1, fig. 4-9) are as follows:

(1) Greatest angle of site measured by the chiefs of sections.



★ Figure 4-8. Determining range to crest.

★ (2) Vertical angle corresponding to 5-meter vertical clearance. This angle is computed by using the mil relation (5 meters divided by crest range in thousands to the near-

est hundred meters). Unless informed otherwise, the executive officer assumes that the crest is occupied by friendly troops.

★(3) Complementary angle of site for elements (1) and (2) above (use comp site factor for crest range to nearest 100 meters).

(4) Site to crest. The site to crest is determined by adding elements (1), (2), and (3) above. This value is rounded to the nearest mil.

(5) Elevation corresponding to range to crest.

(6) Two forks at range to crest.

The sum of elements (1) and (2) is the angle of site to the point 5 meters above the crest. The sum of elements (1), (2), and (3) is the site to the point 5 meters above the crest. The sum of elements (4), (5), and (6) is the quadrant elevation to the point 5 meters above the crest and is reported as the minimum quadrant elevation in the executive officer's report. Elements (1) through (4) are determined to an accuracy of 0.1 mil; elements (5) and (6) and minimum quadrant elevation, to an accuracy of 1 mil.

★*Example:* 155-mm howitzer M109, charge 5 white bag, range to crest 1,100 meters; angles of site reported by chiefs of sections +35, +36, +35, +34, +36, +35.

Solution:

(1) Greatest angle of site	+36.0 mils
(2) Vertical angle corresponding to 5 meter vertical clearance (5/1.1)	+ 4.5
(3) Complementary angle of site (+0.001 X 40.5)	0.0
Total	+40.5
(4) Site to crest (+40.5 expressed as +40)	40
(5) Elevation for crest range	41
(6) Two forks at crest range	4
Total	85

Minimum quadrant elevation reported is 85 mils.

c. If the crest has sectors with significantly different altitudes, it will be necessary to compute more than one minimum quadrant elevation for the sector of fire. In this case, the executive officer reports, for example, AZIMUTH 4850 TO 5200, MINIMUM QUADRANT ELEVATION CHARGE 5 WHITE BAG, 79; AZI-

MUTH 5200 TO 5600, MINIMUM QUADRANT ELEVATION CHARGE 5 WHITE BAG, 86.

d. A single narrow obstruction, such as a tree, which will crest only one piece at a time, is not considered in computing minimum quadrant elevation. If a piece cannot fire safely, it is called out of action.

4-13. VT Fuzes

Fuzes of the M513 and M514 series are variable time (VT) fuzes. A time setting from 5 to 100 seconds may be set on all fuzes of these series. The time element in a VT fuze is armed at 2 seconds after firing or from 3 to 5.5 seconds prior to the time set on the fuze, whichever is later.

4-14. Computation of Minimum Quadrant Elevation for Firing With VT Fuzes (Low-Angle Fire)

a. If the time set on a VT fuze is equal to, or greater than, the time of flight to the crest plus 5.5 seconds, the minimum quadrant elevation computed for other fuzes is used (example 2, fig. 4-9).

★b. If the time set on the fuze is less than the minimum safe time (time of flight to the crest or minimum arming time, whichever is greater, plus 5.5 seconds), the following procedures apply (example 3, fig. 4-9).

(1) Vertical clearances for low-angle fire are as follows:

Weapon	Vertical Clearance
105-mm howitzer	80 meters.
155-mm howitzer	100 meters.
8-inch howitzer	150 meters.
175-mm gun	150 meters.

Note. These clearances should be increased by 50 percent for firing over marshy or wet ground and by 100 percent for firing over water.

(2) The range used in all computations is the crest range (nearest 100 meters) or the range corresponding to a 2-second time of flight, whichever is greater. The range corresponding to a 2-second time of flight is determined from the firing tables; if 2.0 seconds is not listed, the range corresponding to the next higher listed time of flight is used.

(3) The elements used to compute the minimum QE are—

(a) Greatest angle of site as reported by the chiefs of sections.

(b) Vertical angle corresponding to vertical clearance. This angle is computed by dividing the vertical clearance obtained in (1) above by the range obtained in (2) above in thousands of meters expressed to the nearest 100 meters.

(c) Complementary angle of site for elements in (a) and (b) above. Complementary angle of site factor corresponds to the crest range ((2) above) (interpolate for ranges not listed).

(d) Site to crest. The site to crest is determined by adding (a), (b), and (c) above. This value is rounded to the nearest mil.

(e) Elevation corresponding to crest range ((2) above).

(f) Two forks corresponding to crest range ((2) above).

(4) The minimum quadrant elevation reported is the sum of the elements in (d) through (f) above.

★*Example 1:* 155-mm howitzer M109, charge 5 white bag, fuze M514A1, range to crest 1,700 meters, fuze setting 10.0 seconds; angles of site reported by chiefs of sections +40, +39, +40, +38, +39, +40; ground is dry.

Solution: Time of flight to the crest at range 1,700 meters is 4.9 seconds (4.9 seconds plus 5.5 seconds is 10.4 seconds). Range corresponding to 2.0 seconds is 800 meters. Use 1,700 meters.

(1) Greatest angle of site	+40.0
(2) Vertical angle corresponding to 100 meter vertical clearance (100/1.7)	58.8
(3) Complementary angle of site (98.8 X +0.004)	+ 0.4
Total	+99.2
(4) Site to crest (+99.2 expressed as 99)	99
(5) Elevation for crest range ..	67
(6) Two forks at crest range ..	4
Total	170

Minimum quadrant elevation reported is 170 mils.

★*Example 2:* 155-mm howitzer M109,

charge 5 white bag, fuze M514A1, range to crest 500 meters. Fuze setting 0; angles of site reported by chiefs of sections +41, +45, +43, +45, +44, +44; ground is dry.

Solution: Range corresponding to 2.0 seconds is 800 meters. Use 800 meters.

(1) Greatest angle of site	+45.0
(2) Vertical angle corresponding to 100 meter vertical clearance (100/0.8)	125.0
(3) Complementary angle of site (170.0 X 0.001)	0.2
Total	170.2
(4) Site to crest (170.2 expressed as 170)	170
(5) Elevation for 800 meters	30
(6) Two forks at 800 meters	4
Total	204

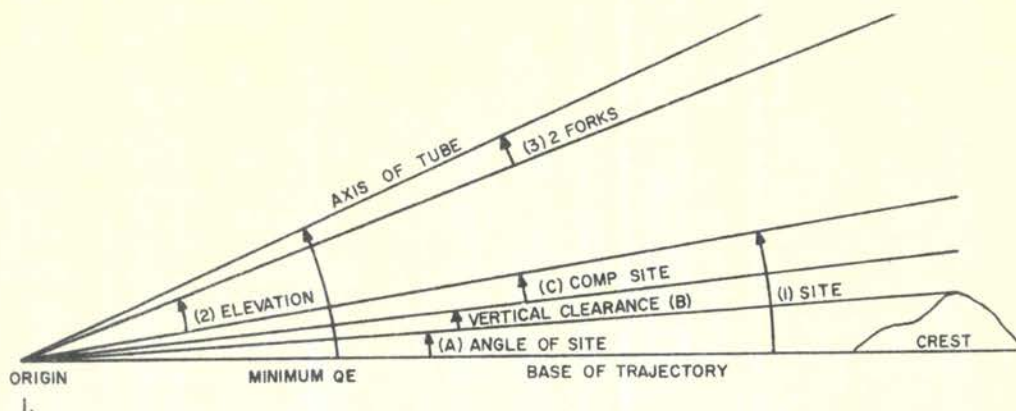
Minimum quadrant elevation reported is 204 mils.

4-15. Minimum Quadrant Elevation Card

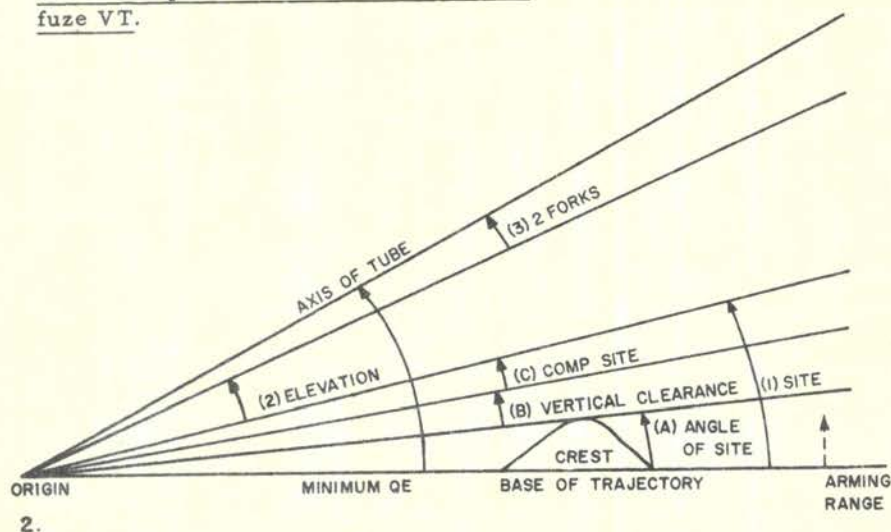
a. The minimum quadrant elevation card contains data which facilitates the computation of minimum quadrant elevation by the executive officer. The table on the card lists, for all charges and selected ranges, the sum of elevation, two forks, the vertical angle corresponding to the appropriate vertical clearance, and the complementary angle of site for +300 mils angle of site. On one side of the card are the data to be used with all fuzes other than VT (table 4-1). On the other side of the card are the data to be used with fuze VT (table 4-2). The side of the card to be used with fuze VT also lists the time of flight plus 5.5 seconds expressed to the next higher whole second for each listed range. When the time set on the VT fuze is equal to or greater than the time listed on the card, the minimum quadrant elevation for fuzes other than VT is used.

b. To determine the quadrant elevation, the executive officer uses the following procedure:

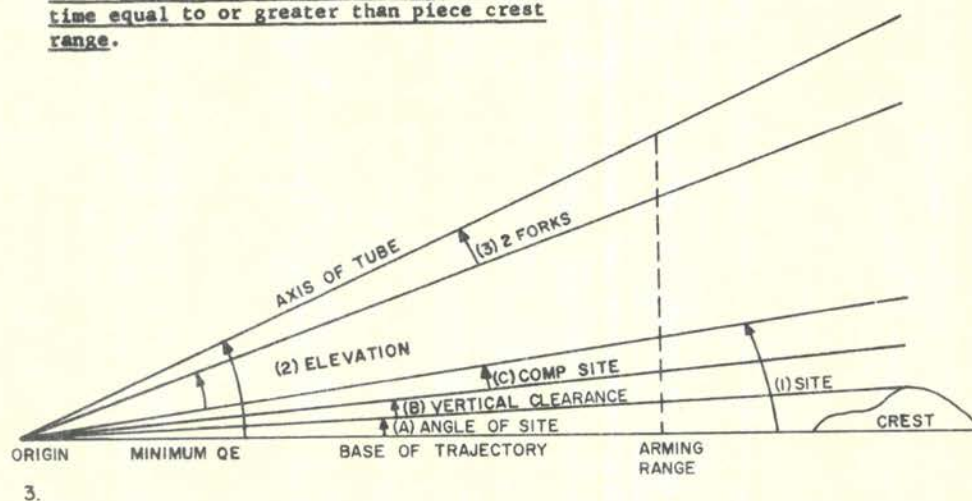
(1) Enter the table at the crest range and determine the quadrant elevation, less site to the crest, for the appropriate charge(s). If the crest range is not listed, enter at the next higher or lower listed range, whichever has the greater value of elevation.



1.
Minimum quadrant elevation, other than fuze VT.



2.
Minimum quadrant elevation, fz VT, arming time equal to or greater than piece crest range.



3.
Minimum quadrant elevation, fz VT, arming time less than piece crest range.

★ Figure 4-9. Minimum quadrant elevation.

(2) Select the greatest angle of site reported by the chiefs of sections.

(3) Add the values determined in (1) and (2) above. The sum is the minimum quadrant elevation.

Example: 155-mm howitzer M109; range to the crest 900 meters. Angles of site reported by the chiefs of sections +80, +78, +79, +80, +78, +79. Determine the minimum quadrant elevation for charge 5 white bag, fuze M564.

Solution: Enter table 4-1 at range 1,000 meters (900 meters not listed).

- (1) Value from the table for charge 5 46
 (2) Greatest angle of site reported +80
 (3) Minimum quadrant elevation 126 mils

c. Examples of minimum quadrant elevation cards with appropriate instructions are shown in tables 4-1 and 4-2.

★Table 4-1. Minimum Quadrant Elevation (Less Angle of Site), 155-mm Howitzer M109, Shell HE M107, Fuzes M557, M500, M520, and M564, FT 155-AH-2

Crest range	Charge (white bag)					Crest Range	Charge (white bag)				
	3	4	5	6	7		3	4	5	6	7
200	42	39	36	34	32	1400	105	81	62	44	32
400	42	36	30	26	22	1600	120	91	70	49	35
600	52	43	34	26	22	1800	134	103	79	55	39
800	63	51	40	30	23	2000	151	116	88	60	43
1000	76	60	46	34	26	2500	193	145	113	77	53
1200	89	70	55	38	28						

Instructions:

1. Enter table at crest range and at the appropriate charge(s). If crest range is not listed, enter at next higher or lower listed range, whichever has the greater value in the body of the table.
2. To obtain the minimum quadrant elevation, add the greatest angle of site reported by the chiefs of sections to the value taken from the body of table.

★Table 4-2. Minimum Quadrant Elevation and Time (Less Angle of Site), 155-mm Howitzer M109, Shell HE, M107, Fuze M514A1, FT 155-AH-2

Crest range	Charge (white bag)									
	3		4		5		6		7	
	El	Ti	El	Ti	El	Ti	El	Ti	El	Ti
200	210	8.0	182	8.0	159	8.0	137	8.0	114	8.0
400	210	8.0	182	8.0	159	8.0	137	8.0	114	8.0
600	211	8.0	182	8.0	159	8.0	137	8.0	114	8.0
800	182	9.0	169	9.0	159	8.0	137	8.0	114	7.0
1000	171	10.0	155	9.0	141	9.0	129	8.0	114	8.0
1200	168	10.0	149	10.0	134	9.0	118	9.0	107	8.0
1400	173	11.0	149	10.0	130	10.0	112	9.0	99	9.0
1600	179	12.0	151	11.0	129	11.0	107	10.0	94	9.0
1800	187	13.0	156	12.0	132	11.0	107	10.0	92	9.0
2000	199	13.0	163	12.0	136	12.0	108	11.0	90	10.0
2500	231	15.0	183	14.0	151	13.0	115	12.0	91	11.0

Instructions:

1. Enter table with range to crest and at the appropriate charge(s). If range to crest is not listed, enter at the next higher or lower listed range, whichever has the greater value listed in the column headed "El."
2. To obtain the minimum quadrant elevation, add the greatest angle of site reported by the chiefs of sections to the value listed in the column headed "El."
3. The minimum quadrant elevation determined using this table is used whenever the fuze setting is less than the value in the column headed "Ti." If the fuze setting is equal to or greater than the value under column "Ti," use the minimum quadrant elevation determined for fuze M564.

Section III. MEASURING AND REPORTING DATA

4-16. Introduction

The battalion fire direction center requires data from the firing battery for various purposes, such as construction of firing charts and checks on laying. The executive officer requires the same data for the charts at the battery fire direction center. The battery executive officer is responsible for reporting the necessary data to the fire direction center. This section describes the executive officer's duties in measuring and reporting data.

4-17. Executive Officer's Report

a. As soon as possible after occupying position and without interfering with firing, the executive officer reports the following data to the fire direction center:

- (1) BATTERY IS LAID.
- (2) AZIMUTH (ORIENTING ANGLE)
(so much), DEFLECTION (so much).
- (3) MINIMUM QUADRANT ELEVATION(S), CHARGE (so-and-so), (so much).

- (4) DISTRIBUTION OF PIECES, NUMBER 1, (so many) METERS RIGHT (LEFT), (so many) METERS BEHIND (IN FRONT OF) BATTERY CENTER; NUMBER 2, etc. The distances from battery center are reported to the nearest 5 meters. The direction in which the battery was laid is used as the reference direction. When time permits, the distribution of pieces should be submitted as a position area sketch (fig. 4-10).

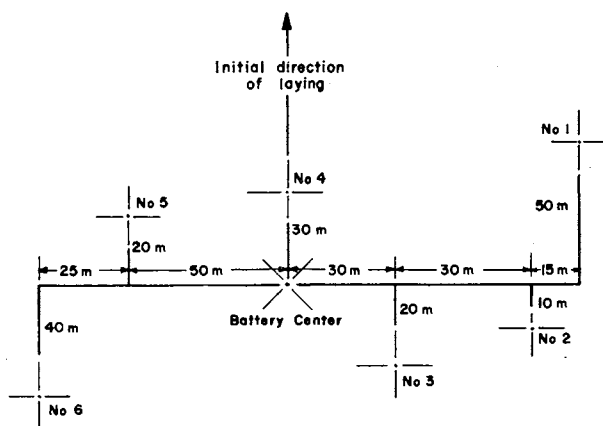


Figure 4-10. Position area sketch

b. In addition to the data reported in *a* above, the executive officer, as soon as time permits, will determine and report the—

- (1) Amount, type, and lot numbers of ammunition.
- (2) Weight of projectile by lot.
- (3) Propellant temperature.
- (4) Lateral limits (azimuths or deflections). These limits indicate the azimuths or deflections between which the pieces can be laid without shifting trails.
- (5) Maximum elevation, when high-angle fire is being used.

4-18. Reporting Adjusted Deflection

After a registration has been completed, the executive officer should determine the adjusted deflection and report it to the fire direction center. The executive officer must determine the adjusted deflection before announcing END OF MISSION to the base piece. He goes to the base piece, verifies the sight picture, and reads the deflection on

the sight. If the sight picture is not correct, he corrects it by referring the sight to the correct picture before reading the deflection on the sight. (The tube must not be moved.) He reports the deflection read as ADJUSTED DEFLECTION (so much).

4-19. Reporting Adjusted Azimuth

In order to report the adjusted azimuth, the executive officer must first determine the adjusted deflection (para 4-18) and then compute the adjusted azimuth by comparing the adjusted deflection to the deflection corresponding to the azimuth on which the battery was initially laid and applying the difference to the azimuth on which the battery was laid.

Example: The battery is laid on azimuth 5000, deflection 3200. After adjustment on the registration point, the FDC commands REPORT ADJUSTED AZIMUTH. The executive officer determines the adjusted deflection to be 3,315 mils. Deflection 3315 is 115 mils to the left of deflection 3200. The executive officer applies left 115 to azimuth 5000 and reports ADJUSTED AZIMUTH 4885.

4-20. Measuring the Azimuth of the Direction of Fire

Upon completion of a registration and prior to announcing END OF MISSION, the executive officer should measure the azimuth and report the measured azimuth to the FDC when required. The procedure for measuring and reporting the azimuth is as follows:

a. Set up the aiming circle away from magnetic attractions and where it can be seen from the base piece. Aline the 0-3200 line approximately parallel to the tube of the base piece.

b. Have the gunner of the base piece, using the panoramic telescope, lay the aiming circle parallel to the tube of the base piece (para 4-5c.)

c. Release the magnetic needle and center it, using the upper motion.

d. Determine the reading on the aiming circle and subtract that reading from the declination constant (adding 6400 to the declination constant, if necessary). The result is the measured azimuth.

4-21. Measuring the Orienting Angle

When an orienting line has been established, the executive officer should measure the orienting

angle (fig. 4-11) upon the completion of a registration and report the measured orienting angle to the FDC when required. The procedure for measuring the orienting angle is as follows:

- Set the aiming circle over the orienting station.
- Have the gunner of the base piece lay the aiming circle parallel to the tube of the base piece.
- With the upper motion, refer to the end of the orienting line.
- The reading on the aiming circle is the orienting angle.

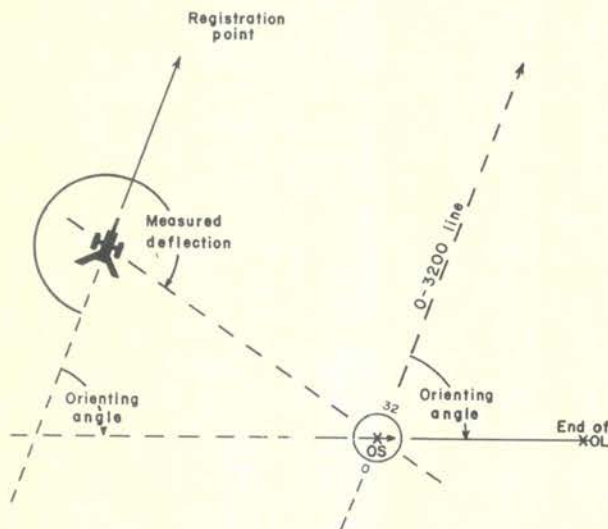


Figure 4-11. Measuring the orienting angle with aiming circle

4-22. Determining Instrument Direction

When the 0-3200 line of an aiming circle is pointing in an unknown direction and it is desired to determine the grid azimuth of that direction, the following procedure is used:

- Release the needle and center it, using the upper motion.
- Subtract the reading on the scales from the declination constant (adding 6400 to the declination constant, if necessary). The remainder is the grid azimuth of the 0-3200 line.

4-23. Measuring Azimuth to a Point

The following procedure is used to measure the azimuth to a point (fig. 4-12):

- Place the aiming circle with the 0-3200 line in an approximate north-south direction with the large 0 of the scale toward the south.

- With the upper motion, set off the declination constant (example one, fig. 4-12).

- Unlock the needle and, with the lower motion, center the needle thus directing the line of sight to magnetic north and the 0-3200 line of the instrument to grid north (example two, fig. 4-12).

- Lock the needle and, with the upper motion, refer the line of sight to the desired point. The grid azimuth to the designated point is read from the azimuth and azimuth micrometer scales (example three, fig. 4-12).

- For greater accuracy, repeat this operation three times and take the average of the readings.

4-24. Correction for Boresighting Error After Registration

- Tactical considerations may require registration prior to making sight tests and adjustments. In such cases, pieces must be boresighted at the earliest practicable time, usually during a lull in firing. If boresighting discloses that the 0-3200 line of the sight (panoramic telescope) was not parallel to the tube, the executive officer must take corrective measures and report them to the fire direction center.

- When a deflection is read from a sight or an azimuth is measured, the deflection or azimuth determined is that of the 0-3200 line of the sight as read from the azimuth counter. Only if the weapon is properly boresighted is the deflection or azimuth that of the tube. When the FDC commands MEASURE THE AZIMUTH (ORIENTING ANGLE), the azimuth (orienting angle) of the tube is desired. Therefore, if the weapon is not properly boresighted, the azimuth (orienting angle) measured is false by the amount of the error in boresighting.

- At the first opportunity after a registration, the base piece is boresighted. The tube is pointed at the aiming point (either a distant aiming point or the appropriate "butterfly" on the test target), and the sight is zeroed. If the sight is pointed to the right of the appropriate aiming point, the tube is pointed to the left of the 0-3200 line of the sight. It follows that any azimuth measured prior to this time was greater than the azimuth of the tube and that any orienting angle measured was smaller than the true orienting angle. If the sight is pointed to the left of the appropriate aiming point, measured azimuths are less than the azimuth

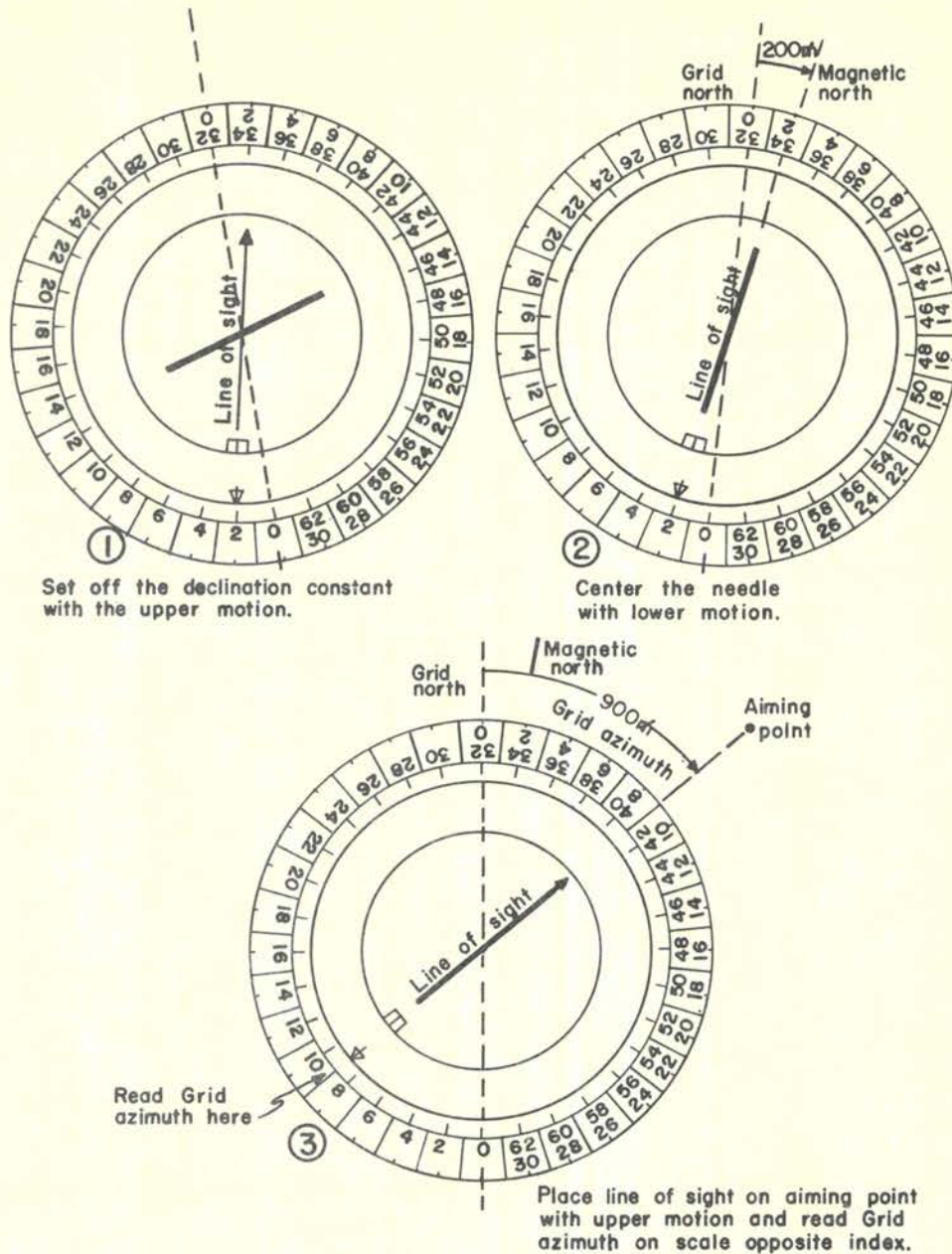


Figure 4-12. Measuring azimuth to a point

of the tube and measured orienting angles are too large. The amount of the error is determined by referring the sight, with the tube still sighted on its aiming point, to the aiming point and reading the deflection. The referred deflection is compared to 3200, and the difference is the amount of the error in boresight. The previously determined azimuths or orienting angles are corrected, the boresighting is completed, and the actions taken are reported.

Example 1: A battery has occupied position and before the base piece can be boresighted, a registration is conducted. At the conclusion of the registration, an adjusted deflection of 2595 is determined by reading the azimuth counter, and an azimuth of 1800 is measured. A short time later, the piece is boresighted. With the tube pointed at the aiming point and the azimuth counter reading 3200, it is discovered that the sight is pointed to the right of the appropriate aiming point. The

sight is then referred to the aiming point, and a deflection of 3,192 mils is read. The tube is pointed 8 mils to the left of the 0-3200 line of the sight (example ①, fig. 4-13). Therefore, the azimuth of the tube after registration was 1792 (1800-8). When the weapon is boresighted, a deflection of 2595 will not point the tube on azimuth 1792. To correct this error, the executive officer adds 8 mils to the adjusted deflection and it becomes 2603 as read on the azimuth counter (example ②, fig. 4-12). The executive officer then directs the base piece to return to the initial lay by setting the azimuth counter deflection at 2600 and the reset counter at 3200. After correcting the boresighting, the executive officer reports **ERROR OF 8 MILS IN BORESIGHTING ON BASE PIECE, CORRECT AZIMUTH WHEN LAID ON REGISTRATION POINT IS 1792, CORRECT ADJUSTED DEFLECTION 3203, BORESIGHTING HAS BEEN CORRECTED.**

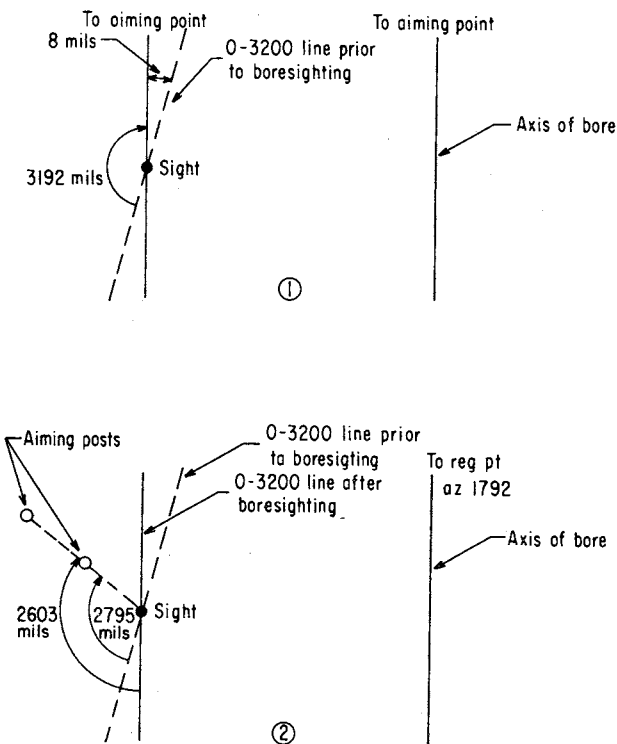


Figure 4-13. Example of error revealed by boresighting

Example 2: Assume that in example 1 an orienting line had been established and that after the registration an orienting angle of 853 mils had been measured. After the 8-mil error in boresight-

ing is determined, the corrected orienting angle is 861 mils (fig. 4-14) and the executive officer reports **ERROR OF 8 MILS IN BORESIGHTING OF NUMBER 3, CORRECT ORIENTING ANGLE IS 861, CORRECT ADJUSTED DEFLECTION 3203, BORESIGHTING HAS BEEN CORRECTED.**

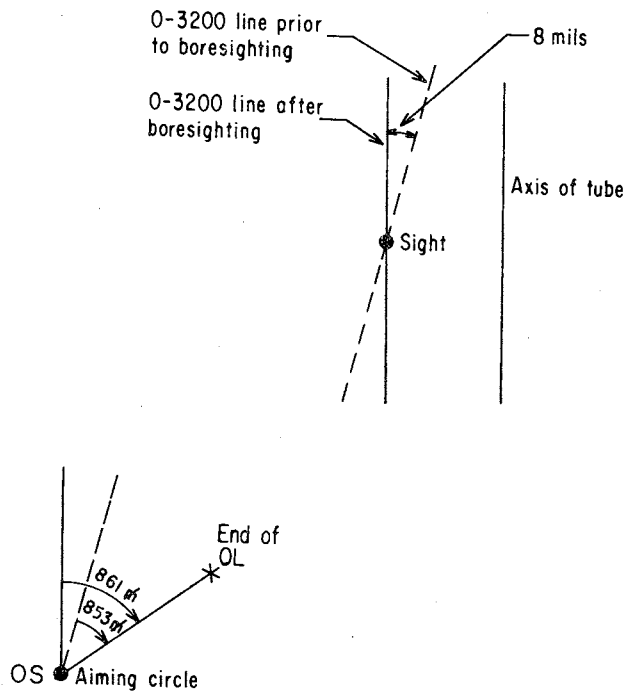


Figure 4-14. Example of error in orienting angle due to error in boresighting

4-25. Site by Firing (Executive Officer's High Burst)

a. Upon completion of an observed firing chart registration with time fuze, the command **OBSERVE HIGH BURST, MEASURE ANGLE OF SITE, 3 ROUNDS**, followed by the adjusted data, may be received from the fire direction center. This command indicates that the FDC desires the executive officer to fire three rounds and to measure and report the observed angle of site to the mean burst center of the three rounds. The executive officer—

- (1) Sets up the aiming circle or BC scope (battery commander's telescope) near the base piece.

(2) Has the gunner lay the instrument reciprocally.

(3) Determines and applies to the adjusted quadrant elevation the angle of site necessary to make the burst visible from the gun position.

(4) Fires three rounds, using the announced adjusted deflection and time and the quadrant elevation determined in (3) above.

(5) Measures, with the instrument, the angle of site to each burst and computes the mean angle of site.

(6) Reports the mean angle of site and the quadrant elevation fired to the fire direction center.

b. See paragraph 26-8 for associated FDC procedures.

4-26. Computation of Deflection Difference

a. A deflection difference is used to achieve a width of sheaf different from the width of the battery front. The sheaf is opened or closed on any desired piece (normally the base piece) a computed number of mils. The amount to open or close the sheaf is determined in the following manner:

(1) Determine the difference between the width of the desired sheaf and the battery front (with respect to the direction of fire).

(2) Divide the value determined in (1) above by one less than the number of pieces in the battery.

(3) Divide the value determined in (2) above by the range in thousands of meters.

b. The sheaf is opened when the width of the desired sheaf is greater than the width of the battery front and closed when the width of the desired sheaf is less than the width of the battery front.

c. No corrections are applied to make the lateral interval between adjacent bursts equal.

Example: A 155-mm howitzer battery is in position with a battery front 250 meters wide. Fire commands are received which include BATTERY ADJUST, SHEAF 100 METERS AT 5000, etc. The executive officer determines the difference (150 meters) between the width of the desired sheaf (100 meters) and the width of the battery front (250 meters). He divides 150 meters by 5 intervals (6 pieces in the battery). The result (30) is divided by the range in thousands of meters (5.0). The amount to be closed is 6 mils. The fire commands to the howitzers will include DEFLECTION 3239, ON NUMBER 3, CLOSE 6.

d. For an explanation of the application of deflection difference by the gunner, see paragraph 4-38c.

4-27. Axial Observer in High-Burst Registration

The executive officer may act as axial observer for a high-burst registration. His instrument must be placed over a surveyed location (battery center or orienting station) and oriented on a surveyed direction. The precise procedures for an observer in a high-burst registration are set forth in paragraph 13-17.

Section IV. FIRE COMMANDS AND THEIR EXECUTION

4-28. Introduction

a. Fire commands convey all the information necessary for opening, conduct, and cessation of fire. Initial fire commands include all elements necessary for laying, loading, and firing the pieces. Subsequent fire commands include only those elements that are changed, except that the range or quadrant elevation is always announced.

b. The basis for fire commands, except in direct fire, is the data processed in the fire direction center. These data are received in requests

for fire; e.g., from an observer, the FDC of another headquarters, or a supported unit. The fire commands are sent to the battery executive officer by the best available means of communication. The executive officer insures that the howitzer (gun) sections receive and execute the fire commands as prescribed in this manual and unit standing operating procedures.

c. Accuracy in the firing battery is dependent on complete understanding of commands by all personnel. Since numbers make up a large portion of all commands received or given

in the firing battery, they must be announced in a clear, precise manner, in a tempo consistent with the execution of the command, and sufficiently loud to be properly understood. Numbers are pronounced as follows:

Number	Pronounced as—
0 -----	Zero
1 -----	Wun
2 -----	Too
3 -----	Thuh-ree
4 -----	Fo-wer
5 -----	Fi-yiv
6 -----	Six
7 -----	Seven
8 -----	Ate
★9 -----	Niner
44 -----	Fo-wer fo-wer
80 -----	Ate zero
100.7 -----	Wun zero zero point seven
136 -----	Wun thuh-ree six
500 -----	Fi-yiv hun-dred
1478 -----	Wun fo-wer seven ate
7000 -----	Seven thow-zand
16000 -----	Wun six thow-zand

4-29. Sequence of Commands

★*a.* Fire commands are announced to the firing battery in the following sequence: see page 4-21.

b. All elements of the fire commands are explained in paragraphs 4-30 through 4-40. Some of the elements are used only under special circumstances and are not announced when they have no practical application.

4-30. Pieces to Follow Commands

The element designating the pieces to follow the commands indicates and alerts those pieces that are to follow commands; this element is always announced in the initial fire commands and is not repeated thereafter. A change of the element (all pieces to follow the commands) during a mission constitutes a new mission, and a new series of commands is given. The command consists of two parts: first, the designation of pieces to follow the command and, second, the word ADJUST. Examples of the designations of pieces to follow are as follows:

a. To alert all pieces, the command is BATTERY ADJUST.

b. To alert the base piece, the command is BASE PIECE ADJUST (NUMBER 3 ADJUST).

c. To alert the left (right) (center) pair of pieces, the command is LEFT (RIGHT) (CENTER) ADJUST.

d. To alert any other combination of pieces, the pieces are designated by number; e.g., NUMBERS 2, 3, 4, and 5 ADJUST.

4-31. Special Instructions

The element *special instructions* is used in the cases discussed in *a* through *d* below.

a. In those cases in which a particular pattern of bursts is desired, the S3 may direct that special corrections be applied. Special corrections are the sum of position corrections and calibration corrections and usually are computed at the fire direction center. When special corrections are to be used in a mission, the command SPECIAL CORRECTIONS is given as the second element of the initial fire commands to alert all personnel that a separate deflection, fuze setting, and quadrant elevation will be announced for each piece throughout the mission.

b. The application of a deflection difference is a rapid method of obtaining a width of sheaf different from the width of a parallel sheaf. When the S3 directs that a deflection difference be applied, the fire commands from the FDC will contain, as the second element, the data necessary for the executive officer to compute the deflection difference; namely, the desired width of sheaf and the range to the target. An example of such a command is BATTERY ADJUST, SHEAF 100 METERS AT 5000, SHELL HE, etc. The desired width of sheaf and the range to the target are not announced to the pieces. The command to the pieces to apply a deflection difference is part of the element of direction (para 4-38c).

c. In units in which the pieces are equipped with an on-carriage elevation fire control, the command USE GUNNER'S QUADRANT is announced as the second element of the fire commands in all missions in which the use of the gunner's quadrant is desired. In units in which the pieces do not have an on-carriage elevation fire control, the gunner's quadrant is used habitually and the command USE GUNNER'S QUADRANT is omitted.

Sequence

When announced

<i>Number</i>	<i>Element of fire command</i>	<i>Example</i>	<i>Initial fire command</i>	<i>Subsequent fire command</i>
1	Pieces to follow commands	BATTERY ADJUST	Always	Never.
2	Special instructions	SPECIAL CORRECTIONS USE GUNNER'S QUADRANT	When applicable	When applicable.
3	Projectile	SHELL HE	Always	When changed.
4	Ammunition lot	LOT XY	When applicable	When changed.
5	Charge	CHARGE 5	Always (except in fixed ammo)	When changed.
6	Fuze	FUZE QUICK	Always	When changed.
7	Pieces to fire	CENTER	Always	When either is changed.
8	Method of fire	1 ROUND, BATTERY 3 ROUNDS TIME IN EFFECT	Always	When either is changed.
9	Direction	DEFLECTION 3239	Always	When changed.
★ 10	Fuze setting	TIME 18.0	When applicable	When changed.
11	Quadrant elevation	QUADRANT 293	Always	Always.

d. When a large deflection shift is indicated, loss of time, caused by shifting trails, can be minimized by announcing a rough azimuth as special instructions immediately following BATTERY ADJUST. Example: BATTERY ADJUST, AZIMUTH 1000.

4-32. Projectile

The type of projectile that will be used to attack the target is always announced in the initial fire commands and is not repeated thereafter, unless a change is desired.

4-33. Ammunition Lot

The element *ammunition lot* indicates the ammunition lot number. Lot number may be announced in the initial fire commands and is not repeated thereafter, unless a change is desired. In fixed and semifixed ammunition the lot number pertains to an assembled, projectile-propellant combination and, for simplicity, may be coded as lot X, lot Y, etc. In separate-loading ammunition when a specific projectile-propellant combination is desired, the lot code may be XY, in which X is the projectile lot and Y is the propellant lot. Large-quantity lots are reserved for registration and subsequent transfers of fire, and the lot number will be announced or prearranged between the FDC and the firing battery. Small-quantity lots should be used on battery observer adjusted missions. The chiefs of sections must segregate ammunition by lot number and keep an accurate record of lots available.

4-34. Charge

The element *charge* indicates the amount of propellant to be used with other than fixed ammunition. If more than one type of propellant is available, the type (white bag or green bag) to be used is designated by announcing, in the initial fire commands, the lot of propellant. If ammunition has numbered charges, the command specifies the number of charges to be fired. If the charges are super, normal, or reduced, they are designated as such instead of by numbers.

4-35. Fuze

A command indicating the type of fuze to be employed is always announced in the initial fire commands and is repeated only when changed.

4-36. Pieces to Fire

a. Any or all of the pieces alerted by the first element of the fire command may be designated to fire. If an adjustment is to be made in area fire, the two center pieces normally will be fired during the adjustment.

b. The element designating the pieces to fire is always announced in the initial fire commands but is not announced in the subsequent fire commands unless either the pieces to fire or the method of fire changes. When all pieces in the battery are to be fired, the command is BATTERY. When any combination of pieces within the battery are to be fired, the pieces are specified by platoon or by number; e.g., LEFT, CENTER, RIGHT, BASE PIECE, NUMBER 1, NUMBER 2, etc.

4-37. Method of Fire

There are a number of methods of fire which can be selected depending on the size, shape, and nature of the target; observation conditions; and other considerations. Although the command for each method is distinctive, it generally consists of two parts—the number of rounds to be fired and the method in which these rounds will be fired. The command is always given in the initial fire commands. In subsequent fire commands, the method of fire is announced only when changed or when the number of pieces to fire is changed. In an area mission in which adjustment is required, the method of fire element in the initial fire commands to the adjusting battery will include, in addition to the method of fire to be used in the adjustment, the pieces to fire for effect, the fuze and/or shell to be used in fire for effect when other than that used in the adjustment, and the method of fire to be used in fire for effect (e.g., CENTER 1 ROUND, BATTERY 4 ROUNDS VT IN EFFECT, or CENTER 1 ROUND, BATTERY 5 ROUNDS IN EFFECT).

a. *Battery (Platoon) (So Many) Rounds.* Unless the FDC has sent a command to hold fire (*d* below), the executive officer will com

mand FIRE when the pieces are ready (fire should not be delayed because of slowness of a portion of the battery). At the command FIRE, all pieces fire their first round. The designated number of subsequent rounds may be fired at the command of the individual chiefs of sections as rapidly as possible consistent with accuracy and without regard to the readiness of other pieces. In area fire, the method of fire by the adjusting pieces is usually CENTER ONE ROUND. The command (so many) ROUNDS AT (so many) SECONDS or (so many) ROUNDS PER MINUTE indicates that single rounds at the time interval specified are to be fired at the executive officer's command. This method may be used to maintain a smoke-screen or illumination.

b. Battery (Platoon) Right (Left). Battery (platoon) right (left) is a method of fire in which weapons are discharged from the right (left) one after the other at 5-second intervals. If a time interval other than 5 seconds is desired, it must be announced as LEFT (RIGHT) AT (so many) SECONDS. If more than one round per piece is to be fired, the command is LEFT (RIGHT), (so many) ROUNDS.

c. Continuous Fire. When it is desired to fire continuously at a target, the command is CONTINUOUS FIRE. At this command, the crews will load and fire as rapidly as possible consistent with accuracy within the prescribed rate of fire for the weapon. Firing will continue until terminated by the command END OF MISSION or until temporarily suspended by the command CEASE LOADING or CHECK FIRING. CANCEL CEASE LOADING and CANCEL CHECK FIRING, respectively, negates the above commands.

★*d. At My Command.* AT MY COMMAND may be announced from the FDC immediately after the method of fire is announced. AT MY COMMAND is part of the method of fire. When the pieces are ready to fire, the executive officer reports BATTERY IS READY to the FDC and fires when he receives the command FIRE from the fire direction center. AT MY COMMAND continues in effect until a new method of fire not including AT MY COMMAND is ordered.

★*e. By Piece At My Command.* When each piece is to be fired individually at a time to be controlled from the FDC, the command is BY PIECE AT MY COMMAND. The pieces are fired by number as ordered from the FDC: e.g., NUMBER (so-and-so) FIRE. When BY PIECE AT MY COMMAND is in effect, the executive officer will report BATTERY IS READY when all pieces are prepared to fire. BY PIECE AT MY COMMAND continues in effect until a new method of fire not including BY PIECE AT MY COMMAND is ordered.

f. Fire At Will. Fire at will is used for direct fire. The command for pieces to fire at will is TARGET (so-and-so), FIRE AT WILL. If a method of close defense has been prearranged, the command is simply FIRE AT WILL. At this command, the designated piece or pieces will fire under the control of the chiefs of sections as the situation and target necessitate.

g. Zone Fire.

(1) Zone fires are delivered in a constant direction at several quadrant elevations. The normal command for zone fire consists of two parts—the number of rounds to be fired at each quadrant elevation and the zone (in mils). The quadrant elevation, announced as the last element of the fire commands, establishes the center of the zone. The normal command is (so many) ROUNDS, ZONE (so many) MILS. The executive officer as the designated pieces fire the announced number of rounds at the announced quadrant elevation and then the same number of rounds at plus and minus the announced number of mils from the center quadrant elevation (e.g., BATTERY 3 ROUNDS, ZONE 5 MILS). Assuming that the announced quadrant elevation is 240, the executive officer has the battery fire three rounds from each piece at quadrant elevation 240, three rounds at 245, and three rounds at 235.

(2) In some cases, the executive officer may receive the command (so many) ROUNDS, ZONE (so many) MILS, 5 QUADRANTS. The executive officer has the designated pieces fire the designated number of rounds at the announced quadrant elevation and then, in any sequence, at four other quad-

rant elevations the announced number of mils apart (e.g., BATTERY 2 ROUNDS, ZONE 5 MILS, 5 QUADRANTS). Assuming that the announced quadrant elevation is 190, the executive officer has the battery fire two rounds at quadrant elevations 190, 200, 180, 185, and 195.

(3) The zone command is not transmitted to the weapons. The executive officer controls the battery by announcing the several quadrant elevations. Because of the large expenditure of ammunition during zone fire, the executive officer must notify each piece as soon as possible the number of rounds to prepare.

h. Shifting Fire.

(1) When the width of the target is too great to be covered with an open sheaf, the target may be attacked by successive shifts.

(2) Shifting fire is accomplished by laying the battery first on one portion of the target and then successively laying it on the other portions to be covered. Fire by the battery is delivered alternately on each portion of the target.

i. Do Not Load. When exact firing data or time of firing has not been determined, it may be desirable for the pieces to be laid but not loaded. In such a case, initial fire commands are sent to lay the tubes and the method of fire command includes the command DO NOT LOAD (e.g., 3 ROUNDS, DO NOT LOAD). As soon as the weapons are laid, the executive officer reports (so-and-so) IS LAID. A subsequent fire command, which includes pieces to fire and a method of fire that does not contain DO NOT LOAD, must be given to cancel DO NOT LOAD.

4-38. Direction

a. The command to lay the tube for direction IS DEFLECTION (so much). This element is always given in the initial fire commands but is given in subsequent fire commands only when changed. The gunner sets off the deflection on his panoramic telescope and then traverses until he is sighted on the proper aiming point. The announced deflection is the sum of the chart deflection and the deflection correction, if any.

b. If special corrections are to be used, the computer at the FDC combines the special

corrections for deflection, the deflection correction, and the chart deflection and announces the total deflection for each piece (e.g., DEFLECTION NUMBER 1,3263; NUMBER 2,3261; etc).

c. If a deflection difference is to be applied, the deflection difference is announced as part of the direction element, following the common deflection (e.g., DEFLECTION 3222, ON NUMBER 3, CLOSE 2). The gunner will apply the deflection difference in the proper direction, equal to the number of mils indicated in the command multiplied by the number of pieces his piece is removed from the one on which the sheaf is being opened or closed. For example, the command ON NUMBER 3, CLOSE 3 is given. The gunners will apply the following correction: NUMBER 1, LEFT 6; NUMBER 2, LEFT 3; NUMBER 3,0; NUMBER 4, RIGHT 3; NUMBER 5, RIGHT 6; NUMBER 6 RIGHT 9. The command for a deflection difference remains in effect until the end of the mission unless a command for another deflection difference is given or the command PARALLEL, which cancels the deflection difference, is given.

d. When a unit is equipped with panoramic telescopes that have gunner's aids, the unit commander may choose to use the command CORRECTION (so much), DEFLECTION (so much) to lay for direction. CORRECTION (so much) is the direction and magnitude of the deflection correction and is announced in the initial fire commands only. The correction is applied to the gunners aid. DEFLECTION (so much) is the announcement of the chart deflection and is always announced in the initial fire commands but is not announced in subsequent fire commands unless there is a change from the last announced chart deflection. The deflection correction must always be applied to the gunner's aid before the chart deflection is set off. When special corrections are to be used, the deflection correction (from the deflection correction scale) and the special correction for deflection are combined and the total deflection correction for each piece is announced as CORRECTION, NUMBER 1 LEFT (RIGHT) (so much), etc, prior to the announcement of the common (chart) deflection.

4-39. Fuze Setting

★*a.* When time fuze in effect has been specified, a fuze setting will be required in the fire commands after the adjustment with fuze quick and is reannounced only when changed. The same procedure applies when a fuze setting with VT fuze is used. Fuze setting for time fuze is computed and announced to the nearest tenth (e.g., TIME 17.4) but fuze setting for VT fuze is announced as a whole number expressed to the tenth (e.g., TIME 17.0 or 21.0).

b. When special corrections are to be used, the special correction for fuze setting and the common fuze setting are combined by the computer and the total fuze setting for each piece is announced (e.g., TIME, NUMBER 1, 28.4; NUMBER 2, 28.6; etc).

4-40. Quadrant Elevation

a. Quadrant elevation is the sum of elevation plus site. The command to lay for quadrant elevation is QUADRANT (so much).

b. When special corrections are to be used, the special correction for elevation is added to the common quadrant elevation and the total quadrant elevation for each piece is announced (e.g., QUADRANT, NUMBER 1, 293; NUMBER 2, 296; etc).

c. The command for quadrant elevation is the command to load the piece, except when DO NOT LOAD is a part of the method of fire or when a salute is being fired.

d. Unless the method of fire includes BY PIECE AT MY COMMAND, AT MY COMMAND, or DO NOT LOAD, the command for quadrant elevation received from the FDC gives the executive officer the authority to fire when ready. When all pieces to fire are ready, the executive officer commands FIRE. The chiefs of sections will repeat the command FIRE as it is given. The command FIRE should be delayed only when a substantial reason exists; for example, a safety or accuracy check.

4-41. Examples of Fire Commands

All commands are repeated by the executive officer or designated personnel of the firing battery unless otherwise noted.

a. An example of initial commands for a precision registration is—

BASE PIECE ADJUST
SHELL HE
LOT XY
CHARGE 4
FUZE QUICK
BASE PIECE, 1 ROUND
DEFLECTION 3450
QUADRANT 315

b. An example of initial commands for zone fire is—

BATTERY ADJUST
SHELL HE
LOT XY
CHARGE 5
FUZE QUICK
BATTERY 1 ROUND
ZONE 4 MILS
DEFLECTION 3480

QUADRANT 268. (quadrant elevations 268, 272, and 264 will be fired.)

4-42. Check Firing

The command CHECK FIRING, normally, is given by the executive officer, but, in an emergency, may be given by anyone present. This command is immediately repeated to the battery by the first individual receiving it. At the command, regardless of its source, firing will cease immediately. If this command originated from the observer or FDC and the piece is loaded, the executive officer reports NUMBER 2 (or other piece) LOADED. If firing is stopped by someone at the position, the executive officer reports that fact and the reason therefore to the fire direction center. Firing is resumed at the announcement of CANCEL CHECK FIRING followed by the quadrant.

4-43. End of Mission

The command END OF MISSION means that the fire mission has been completed.

4-44. Repetition of Commands

a. By Chief of Section.

(1) *Voice communication.* Chiefs of sections repeat the commands FIRE and CHECK FIRING. Any other commands given by the

executive officer are repeated only when requested or when they obviously have not been heard or understood. The request for repetition is a question (e.g., DEFLECTION NUMBER (so-and-so)?; QUADRANT NUMBER (so-and-so)?

(2) *Intrabattery communication.* When wire communication is used between the executive officer's command post and the individual sections, the read-back of elements of the fire commands will be governed by unit standing operating procedure. The cannoneer operating the telephone must announce each element of the fire commands to his section.

★*b. By Executive Officer.* The repetition of commands by the executive officer or the person transmitting commands to the pieces after he has announced them is always preceded by THE COMMAND WAS (e.g., THE COMMAND WAS, DEFLECTION 2768). When special corrections have been announced as a special instruction, the person transmitting the commands should repeat the special corrections for that piece as it relates to that element of the fire commands (e.g., THE COMMAND WAS NUMBER 3, TIME 21.8).

4-45. Signals

Arm and hand signals are used in conjunction with oral commands to achieve greater clarity. The chief of section extends his right arm vertically, with palm of hand toward the executive officer (the *ready* position), to indicate that his piece is ready to fire. When he cannot be seen by the executive officer, he reports orally NUMBER (so-and-so) READY. The commands FIRE and CHECK FIRING usually are given by arm signals as well as by voice. The signal for FIRE is either to drop the right arm sharply from the *ready* position to the side or to point with the right hand at the piece to be fired, extend the arm to the *ready* position, and drop it sharply to the side. The signal for CHECK FIRING is to raise the hand in front of the forehead, palm to the front, and swing hand and forearm up and down in front of the face.

4-46. Final Protective Fires

a. The battery final protective fire (FPF) is

designed to be fired quickly on a critical line or area. It is a high priority fire, taking precedence over all other fire missions. When the battery is not firing other missions, it is laid on its final protective fire and appropriately prepared rounds are kept at the pieces.

b. The final protective fire may be initiated by the command FIRE THE FINAL PROTECTIVE FIRE or by a prearranged signal. When personnel are resting, the piece sentinels begin firing immediately on the command FIRE THE FINAL PROTECTIVE FIRE or on receipt of the prearranged signal.

4-47. Reports

The executive officer reports to the FDC all actions that affect the firing of the battery. In addition to those reports previously mentioned (BATTERY IS READY, BATTERY IS LAID, CHECK FIRING), the following specific reports are made.

a. SHOT (NUMBER 1 SHOT)—when the first round of a series has been fired. This report is preceded by the piece that is firing only when information is necessary for coordination; e.g., BY PIECE AT MY COMMAND.

b. ROUNDS COMPLETE—when the number of rounds specified in fire for effect have been fired (other than so-and-so 1 round).

c. MISFIRE NUMBER (so-and-so)—when there has been a misfire. NUMBER (so-and-so) IS READY—when again ready to fire, if fire mission has not been completed.

d. NUMBER (so-and-so) IS OUT (reason)—when a piece has been called out.

e. Number of rounds expended, by type (and lot number when required)—at the completion of each fire mission.

f. Errors—chiefs of sections must report immediately to the executive officer all errors that have caused a round to be fired with incorrect data. The executive officer has these errors corrected and reports to the FDC; e.g., NUMBER 2 FIRED 20 MILS RIGHT; ERROR HAS BEEN CORRECTED.

4-48. Checking Settings During Firing

The executive officer usually checks settings and laying during lulls in firing. When the executive officer questions the accuracy of the

laying of any piece he calls that piece out, reports that fact to the FDC, and has the necessary checks made. When the battery is firing close to friendly troops, frequent checks must be made to insure safety.

4-49. Correcting Fire Commands By Executive Officer

a. If an incorrect command has been an-

nounced but FIRE has not been given, CORRECTION is given, followed by the correct command and all subsequent elements.

b. If FIRE has been given, the executive officer announces CHECK FIRING. He then announces CANCEL CHECK FIRING and gives the correct command followed by all subsequent elements. Firing continues with the announcement of QUADRANT.

Section V. ASSAULT AND DIRECT FIRE

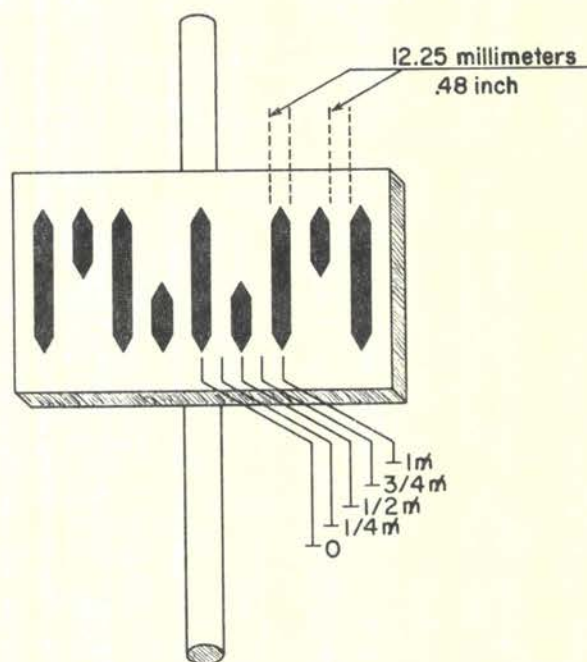
4-50. Assault Fire

a. Assault fire is a special technique of indirect fire. Fire is conducted at a relatively short range to attain pinpoint accuracy against a stationary target. The gun-target range is sufficiently short to make possible successive hits on the same portions of the target. Only one piece is used on a mission, and the FDC for the mission normally is located at the gun (howitzer) position. Thorough planning, reconnaissance, and coordination must be completed before the gun (howitzer) position is occupied.

b. Any artillery cannon can be used for assault fire; however, any caliber smaller than 155-mm is considered uneconomical. The most efficient weapons, in order of preference, are the 8-inch howitzer, the 155-mm howitzer, and the 175-mm gun. Self-propelled versions of these weapons are best suited in many instances for this task because of their maneuverability and ease of emplacement and displacement. When the maximum charge is used, maximum effective assault fire ranges are 3,000 meters for the 8-inch howitzer and 2,500 meters for the 155-mm howitzer and the 175-mm gun.

4-51. Assault Fire Procedure

★a. In order to make the small deflection changes which are necessary in assault fire, a special technique of laying is employed at the piece. Deflection changes are made to the nearest mil until a 1-mil deflection bracket has been obtained; further changes are made to the nearest one-fourth mil on weapons equipped with the M100 series sights. On other sights a



★Figure 4-15. Deflection board.

deflection board attached to an aiming post is used for this purpose. The deflection board (fig. 4-15) enables the gunner to make deflection changes to one-fourth mil. The black and white bands (lines) are one-fourth mil in width when viewed through the sight of the piece at a distance of *exactly 50 meters*. The gunner lays on the desired portion of the board by centering the vertical cross hair of the sight upon a black (white) band on the board. To move one-fourth mil, he moves the line of sight by traversing the piece in the proper direction,

so that the adjacent white (black) band is covered; to move one-half mil, he moves the vertical cross hair two bands, etc.

b. Changes in elevation are made to the

nearest 0.1 mil; the gunner's quadrant is used.

4-52. Direct Fire

Firing by direct laying is a special technique that demands a high standard of training. The

section must operate as an independent unit. Enemy targets taken under fire by direct laying procedures are usually those capable of returning fire at pointblank range; therefore, the speed and accuracy required in direct fire are of the utmost importance.

a. Methods of Sighting.

- (1) *Two-man, two-sight.* Using the two-man, two-sight system, the gunner establishes lead with the panoramic telescope and the assistant gunner establishes elevation with the direct fire telescope. This system is the fastest and most accurate and permits the assistant gunner to check the direction of lead. A canted reticle in the direct fire telescope will prevent satisfactory direct fire on moving targets because an unacceptable range error is introduced when lead is changed.
- (2) *Two-man, one-sight.* Using the two-man, one-sight system, the gunner establishes lead with the panoramic telescope and the assistant gunner sets elevation on the elevation quadrant at the command of the chief of section. This system is most effective when the target is moving on flat terrain.
- (3) *One-man, one-sight.* Using the one-man, one-sight system, the gunner lays for lead and elevation with the reticle of the pan-

oramic telescope. This system should not be used if the target is moving on a steep slope.

b. Methods of Laying.

- (1) *Reticle laying with deflection zero.* The gunner maintains lead by placing the verticle hairline the proper number of mils ahead of the center of the target.
 - (a) *Continuous tracking.* Lead and elevation are laid and maintained in tracking the target.
 - (b) *Laying ahead.* The gunner does not track the target but lays ahead of it for lead and adjusts the elevation as the target approaches the correct lead.
- (2) *Central laying.* The gunner sets the lead in mils on the azimuth micrometer scale of the panoramic telescope and maintains the verticle hairline of the rectile on the center of the target. A modification on the knob of the panoramic telescope, called click sights, permits the gunner to set off lead in 5-mil increments, by sound or feel, without removing his eye from the sight.

c. Direct Fire Characteristics. The direct fire characteristics of current standard field artillery weapons vary widely. For a discussion of a particular weapon, see the field manual for the weapon involved.

CHAPTER 5

FIRING BATTERY OPERATIONS AND TRAINING

Section 1. GENERAL

5-1. Introduction

Field artillery doctrine demands the delivery of timely and accurate fires. The firing battery, as part of the gunnery team, bears a large share of the responsibility for the delivery of effective fire. The battery executive officer is in direct charge of the training and operation of the firing battery. During training he must institute practices and procedures which will assure the accurate and timely execution of fire commands.

5-2. Principles of Training

a. Proper training of the firing battery starts with training of each individual in the specific duties in service of the piece prescribed in the appropriate manual. Next is the training of the section as a team. Finally, the sections are brought together and trained as the firing battery. Standing operating procedures must be developed as training progresses.

b. Accuracy must be emphasized in the initial stages of each phase of training. As training progresses, speed is gradually gained but loss of accuracy is not tolerated.

c. The firing battery must be trained to occupy position and execute fire commands during darkness and inclement weather.

5-3. Conduct of Service-of-the-Piece Drill

a. Successful operation of the firing battery depends primarily on instilling pride in the rapid and precise execution of all commands. The success of service-of-the-piece drill depends on the ability of the chiefs of sections and the executive officer and his assistants to recognize unsafe, incorrect, inaccurate, or careless performance of duties by individuals. Service-of-the-piece drills provide practice and test the whole team as well as the individual members. Pieces should be placed close together to facilitate observation and supervision. Telephone communications may be installed to train section personnel in the use of telephones for receipt of commands.

b. Drills should be kept interesting, short, and snappy, with frequent rests. The gunner and all cannoneers may exchange positions after personnel have gained full proficiency in their own jobs. The executive officer frequently should time the sections with a stopwatch to emphasize speed as well as accuracy. Specific individuals should be assigned to observe and check specific items. The use of command cards will speed and improve the conduct of the drill. Occasionally, the chiefs of sections should be drilled separately in the setting of the gunner's quadrant including settings to the nearest 0.1 mil.

c. The battery must be trained to execute all possible fire commands. Large changes in deflection and elevation (greater than 100 mils) should be included in some commands to facilitate checking for 100-mil errors. Changes in deflection that require shifting of trails should be avoided except when training is being conducted in trail shifting. The method of fire should be changed frequently to teach the various methods of fire, to increase alertness, and to insure familiarity with all commands so that no command during firing will surprise any member of the firing battery. As training progresses, more difficult commands should be included and more difficult situations presented.

5-4. Accuracy Requirements

Some of the standards which must be met during all service-of-the-piece training (firing or drill) are listed in *a* through *h* below.

a. Bubbles. After the breech is closed and before firing, the bubbles must be centered exactly.

b. Indexes. The proper graduation must be aligned exactly with the index.

c. Micrometer Knobs. When the scales are being set, the last motion of the micrometer knobs must be from the lower to the higher reading.

d. Traverse. The last motion of the traversing handwheel should cause the vertical hairline of the panoramic telescope to approach the aiming

point from left to right; if the collimator is being used, the appropriate lead line in the reticle pattern of the panoramic telescope should approach the aiming point from left to right. If the vertical hairline or appropriate lead line passes the aiming point, the handwheel should be turned back one complete turn and a new approach made. The gunner must be trained to habitually lay with the left edge of the vertical hairline on exactly the same portion of the aiming point (left edge of the aiming posts when exactly vertical) or with the appropriate lead line lined up with the number displayed in the collimator.

e. Fuze Setters and Fuzes. Settings on the fuze setter should be made with the last motion in the direction of increasing readings.

f. Elevation. When the tube of any field artillery piece is elevated or depressed, the last motion of the handwheel should be in the direction which offers the greatest resistance. If the bubble level point is passed, the handwheel should be turned back one complete turn before the bubble is centered.

g. Aiming Posts. The far aiming post should be approximately 100 meters from the sight of the piece. The near aiming post must be one-half the distance to the far aiming post. The chief of section and the gunner must check to insure that the aiming posts are placed at the proper distances and that they are exactly vertical and alined.

h. Uniformity in Ramming. Uniform ramming

helps prevent unusual variations in muzzle velocity. Nonuniform ramming may cause variation in seating, escape of propellant gases around the projectile, and variation in the effective size of the powder chamber. These factors will in turn cause range inaccuracies. Hard ramming is essential to safety. If the projectile is not seated firmly, particularly at high quadrant elevations, it may slip back into the powder chamber and rest on the charge. If the weapon is fired with the projectile in this position, premature detonation may occur, causing a serious accident.

5-5. Equipment Checks

a. All fire control equipment must be in correct adjustment. All section equipment, especially sighting and laying equipment, should be checked frequently for serviceability and completeness. Sighting and laying equipment should be checked immediately after the battery goes into firing position. Some tests and adjustments are made periodically or when the need is evident. Only those adjustments authorized in the technical manual for the weapon may be made by battery personnel.

b. Boresighting is the process by which the optical axes of the panoramic and elbow telescopes are made parallel, both vertically and horizontally, to the axis of the bore, when the scales of the mounts and telescopes are set at zero or 3200 as appropriate. (See specific weapon field manual for methods of boresighting.)

Section II. FIELD OPERATION OF FIRING BATTERY

5-6. Duties of the Battery Executive Officer

The duties of the battery executive officer are as follows:

a. Prior to leaving the motor park or assembly area, he—

- (1) Insures that equipment and ammunition is complete, serviceable, and properly stored.
- (2) Makes a reconnaissance of the new position, if feasible, and determines zone of fire or safety limits.

b. At the firing position, he—

- (1) Supervises occupation of position.
- (2) Lays or verifies the laying of the battery.
- (3) Checks communications.
- (4) Has personnel recheck recoil mechanisms and adjustment of instruments.

- (5) Determines minimum quadrant elevations.
- (6) Gives executive officer's report to the FDC.
- (7) Has the pieces boresighted when time permits.
- (8) Controls the delivery of fire as requested by the observer when the mission is being conducted by the battery or as commanded from the FDC when the mission is being conducted by the battalion.
- (9) Is responsible for insuring compliance with safety rules.
- (10) Insures uniform and adequate storage of ammunition.
- (11) Supervises accounting of ammunition to include lot segregation and control.

(12) Supervises fire direction at the battery.

c. Prior to entering combat (actual or simulated), he insures that the firing battery is capable of—

- (1) Twenty-four-hour operation.
- (2) Efficient occupation and organization of the position.
- (3) Passive defense of the position through proper camouflage and light discipline and other measures.
- (4) Active defense of the position by direct laying of the pieces, by use of other organic weapons (machineguns, rocket launchers, and small arms) and by use of mines and trip flares.
- (5) Operating efficiently within safety rules.

5-7. Duties of the Recorder

a. The recorder is an assistant to the battery executive officer. As his title implies, he maintains certain records for the executive officer and installs and operates necessary telephones. Among those records that he maintains are—

- (1) DA Form 3623 (Firing Battery Recorder's Sheet) on which he records laying data, fire commands, and a running total, by type and lot, of ammunition on hand in each section (fig. 5-1).
- (2) A file of prearranged fires to include the final protective fire data.
- (3) A record of minimum quadrant elevations and referred deflections for each weapon.

b. When directed, the recorder announces fire commands to the pieces.

5-8. Records and Data Maintained in the Firing Battery

In addition to the recorder's sheet (para 5-7), the following records are also kept in the firing battery and must be checked by the executive officer for completeness and accuracy:

a. A Firing Battery Section Data Sheet (DA Form 3-13) (fig. 5-2) is usually prepared by the FDC for prearranged and close-in defensive fires. The section data sheet contains the information necessary to permit the chief of section to fire the listed targets. The chief of section is responsible for announcing the fire commands directed on the section data sheet.

b. The U.S. Army Equipment Log Book is used for recording the history of the carriage or mount and the tube data. DA Form 2408-4, Weapon Record Data which is filed in the equipment log book, serves as a permanent life history of a weapon and must accurately reflect the ammunition fired and the date of firing. Entries must be checked periodically, especially calibration data and ordnance service entries. Maintenance records kept by the artillery mechanic must be current to supplement data in the weapon record book.

FIRING BATTERY RECORDER'S SHEET										Battery A		Date 19 Aug 68		Page number 1					
For use of this form, see FM 6-40; the proponent agency is U.S. Continental Army Command.																			
Battery laid on										Ammunition and Fuzes on hand									
Azimuth 1620		Azimuth of OL 2150		Orienting Angle 530		Deflection 3200				HE X	HE V	HE T	WP W	SMK Z	GB Y	WB U	M 57	M 564	M514 B-1
Fire commands										200	100	50	30	20	300	100	200	100	50
Pieces to follow	Sp Instr	Sh	Lot	Chg	Fz	Pieces to fire/MF	Df	Ti	QE	Ammunition Expended									
BA	AZ 1800	HE	XY	5	Q	20 80 UT	3070	-	306	②					②		②		
							3036	-	314	④					④		④		
							3042	-	310	⑥					⑥		⑥		
					VT	80		19.0	310	⑫					⑫				⑥
				EM	TGT	AF 7001				188	100	50	30	20	288	100	194	100	44
BA	SP CARR	HE	XU	7	TI	B ③ AMC													
						#1	3148	14.8	228										
						#2	3150	14.8	229										
						#3	3151	14.9	231										
						#4	3153	14.9	232										
						#5	3154	14.8	228										
						#6	3155	14.8	227	⑮					⑮		⑮		
				EM	TGT	AF 4036				170	100	50	30	20	288	82	194	82	44
#6 A	USQ	HE	TY	5	D	#60	0018		367.3			①			①		①		
	AZ 4700						0019		368.0			④			②		②		
				EM	TGT	AF 7002				170	100	48	30	20	286	82	192	82	44

DA FORM 3623

REPLACES DA FORM 6-17, 1 AUG 62, WHICH IS OBSOLETE.

Figure 5-1. Firing Battery Recorder's Sheet
(DA Form 3623).

FIRING BATTERY SECTION DATA SHEET (FM 6-40)							SECTION 1		BATTERY B		DATE 13 MARCH		PAGE NO. 1	
CONC. NO.	TIME		AMMUNITION				METHOD OF FIRE	CORR	DF	TIME	QE.	REMARKS		
	FROM	TO	SH.	LOT	CHG	FZ.								
AF 2403	0515	0519	HE	XY	5	Ti	B(8)		3362	17.5	260			
AF 2405	0522	0524	HE	XY	5	Q	B(2)		3261		236			
AF 2412	0525	0527	HE	XY	5	VT	B(4)		3181	14.5	218 221 215	ZONE 3 m		
AF 2410	0528	0530	HE	XY	5	Q	B(4)		3518					
FPF	ON CALL		HE	XY	4	Q	CONT. FIRE	# 1	3314		217			
								# 2	3316		216			
								# 3	3313		217			
								# 4	3315		213			
								# 5	3317		215			
								# 6	3316		218			

DA FORM 6-13
1 DEC 63

REPLACES DA FORM 6-13, 1 MAR 57, EXISTING SUPPLIES OF WHICH WILL BE ISSUED AND USED UNTIL 1 DECEMBER 1964 UNLESS SOONER EXHAUSTED.

GPO 805-853

Figure 5-2. Firing battery section data sheet

Section III. CARE AND HANDLING OF AMMUNITION

5-9. Ammunition References

The technical manual issued with each weapon lists the authorized ammunition and the marking and packing and other technical information. For a general discussion of ammunition, see TM 9-1900; for characteristics of all types of artillery ammunition, see TM 9-1300-203.

5-10. General Safety Precautions

a. Careful handling of ammunition is necessary to insure proper functioning and to avoid accidents. Since accuracy of fire is affected by damaged ammunition, the care and handling of artillery ammunition must be carefully supervised. Firing battery personnel must have a detailed knowledge of the marking, purpose, and functioning of each component.

b. Basic principles of ammunition handling for firing battery personnel are as follows:

- (1) Know in detail how to assemble and prepare the ammunition.
- (2) Do not tumble, drag, throw, or drop boxes or components.
- (3) Do not allow smoking, open flames, or other fire hazards around ammunition.
- (4) Inspect each round prior to use to insure that it is clean, properly assembled, and otherwise suitable for use.
- (5) Protect all components from moisture, extremes of temperature, and corrosive chemicals.
- (6) Never make unauthorized alterations on the ammunition or mix components of one lot or round of ammunition with that of another.
- (7) Do not reuse cartridges or projectiles which have been extracted from weapons by ramming. Extraction difficulty may have been caused by some nonstandard condition or the fuze may have been damaged during extraction.

5-11. Projectiles

a. Projectiles must be inspected to insure that there is no leakage of the contents, that they are correctly assembled, and that bourrelets and rotating bands are smooth and free of burs and large dents. If rotating bands are burred or nicked,

they should be smoothed with a flat, fine-grained file or with crocus cloth backed with a small block of wood. Projectiles, especially those without the fuze and booster assembled, are relatively safe from detonation by small-arms fire or shell fragments. Lifting plugs on separate-loading ammunition should be kept tight in the shell nose until the projectile is ready for use. This will prevent moisture from affecting the explosive and prevent rust from freezing the lifting plug in place. Rotating band grommets must be secure and tight to prevent nicking and scarring the comparatively soft rotating bands.

b. High-explosive projectiles issued for use with VT fuzes are standard projectiles with the fuze and booster cavities deepened to accommodate the longer VT fuze. These deep cavity projectiles are issued with a removable supplementary charge so that they may be used with either impact, mechanical time, or VT fuzes. The supplementary charge is removed only when the projectile is used with a VT fuze and must be in place when used with a mechanical time or impact fuze.

Warning: Do not attempt to remove the supplementary charge by any other means than the lifting loop. If the charge cannot be removed by the lifting loop, the round may be disposed of or fired with a PD, MT, or MTSQ fuze. The deep cavity may be lined with a paper tube and bottom cup which helps support the high-explosive filler. This lining will not be removed at any time.

5-12. Propelling Charges

a. Care must be exercised to insure that all increments of a propelling charge are present and of the same lot number and that only the proper increments are removed from the complete charge before firing. The cannoneer preparing a propelling charge for firing must count and identify by number not only the increments removed from a charge but also the increments not removed. This precaution will help eliminate mistakes in the preparation of the charge and will also detect missing or duplicate increments. Propellant bags should not be torn or ripped, and there should be no leakage of contents. With separate-loading ammunition, the data tag and igniter pad cover

must be removed before the charge is loaded. Ammunition which has been prepared for a certain charge should be carefully segregated from other ammunition. Charges for which firing is not immediately planned should be resealed. Increments removed from a prepared charge are left with the charge until the charge is fired so that, if necessary, a higher charge than originally planned may be fired or ammunition repacked conveniently. Increments left over from charges already fired are immediately removed to a point 30 to 40 feet from the nearest weapon or ammunition until the battery personnel can dispose of them.

b. It is not practical to salvage unused increments. Unused increments may be burned in the open in small quantities. If large quantities of unused increments are burned, they may explode. When it is necessary to destroy igniter pads, they should be separated from the base charge and handled in accordance with the provisions of TM 9-1300-206. Igniter pads should never be cut open with a metallic object, such as a knife, for premature ignition may result.

c. Propelling charges absorb moisture and should be kept in the containers until just before use. This precaution reduces the danger of fire from sparks, blowbacks, small-arms fire, and hot shell fragments. Propellants must also be protected from excessive and rapid changes in temperature and from the direct rays of the sun. High temperature greatly accelerates the normal rate of deterioration and causes excessive and irregular chamber pressures in firing, resulting in erratic ranges (para 2-9g(5)). Sudden changes in temperature may also cause moisture to condense on the charges. At the battery position, the propellant temperature of ready ammunition (propellant charges) that is representative of ammunition designated for early use should be checked periodically. The rounds or propellant charges so checked should not be removed from the rest of the ammunition but should be measured in place to get a true mean. The thermometer should penetrate the charge that is being used, and it must not touch any metal.

5-13. Cartridge Cases

Cartridge cases should be inspected carefully for cracks or dents which might affect their

functioning. Care is necessary in handling cartridge cases, for they are easily dented. Care must be taken to protect the base of a cartridge case, which, if struck, may cause accidental firing of the primer. A badly corroded cartridge case is difficult to extract from the chamber and may rupture. With semifixed ammunition, it is important that the mouth of the case be not deformed. A deformed case is difficult to load and may result in a serious blowback if fired.

5-14. Fuzes

a. A fuze is sensitive to shock. Moisture or high temperature may impair the functioning of a fuze. A fuze should be inspected carefully to ascertain that it is properly assembled and set. A separate fuze should be tightened as much as possible by hand and then should be firmly seated with a sharp snap of the M18 fuze wrench. Care must be taken to start the mesh of the threads properly. When a fuze is not tightly seated, premature detonation may occur through sudden seating from rotation in the bore. With fixed and semifixed ammunition, the packing stop must be removed before firing.

b. The initial fuze settings for nonadjusting pieces in a mission requiring adjustment or in a mission whose method of fire includes DO NOT LOAD, will not be set on mechanical time and variable time fuzes. When the mechanical fuze setter is used, the time announced is set on the fuze setter but the fuze is not set until a method of fire is received that permits loading of the weapon. When a wrench type fuze setter is used the fuze will not be set until a method of fire is received that permits loading of the weapon. This will preclude setting the fuze more than once if a different fuze setting is required when the final time is announced. A time fuze which has been set but not fired is reset to SAFE, and the safety pin is inserted before the fuze is replaced in the container.

c. A fuze setter graduated to suit the fuze is required for a time fuze for accurate and rapid setting. A number of models of fuze setters have been standardized. The details of the use of fuze setters are contained in the appropriate field manual for the weapon.

d. Variable time fuzes (fig. 5-3) belong to a class of special fuzes that require specially

loaded projectiles. The length of the fuze booster assembly of a VT fuze is longer than that of a standard impact fuze. The ogives of some of the fuzes have a heavy coating of wax that must not be removed. The VT fuze is completely boresafe and muzzlesafe. The arming mechanism of the M513- and M514-series fuzes provides an additional safe period during the first 2 seconds' time of flight. A fuze setting is made manually with a mechanical fuze setter. It is important that the time scale of the fuze setter correspond to the time ring of the fuze (0-100 with either the M513 or M514 series). The individual setting the fuze should look down on the nose of the fuze and rotate the cap in a clockwise direction, which is the direction of increasing readings. In the event the fuze setter M14 or M27 is used and the desired setting is passed, the clockwise rotation of the cap is continued until the desired setting is again reached. The cap should not be "backed up" to the setting, because this introduces backlash and reduces timing accuracy. The zero setting line (2.0 seconds) is the lowest point at which VT action can be expected from the fuze. The ammunition caliber is stenciled on the fuze body. For details on the care and use of fuzes, refer to appropriate ordnance technical publications.

Note. The M513 (T226), M513B1 (226B1), M514 (T227), and M514B1 (T227B1) fuzes do not have a PD setting and should not be used when PD action is desired. The PD element is armed by the VT element and is for self destruction only.

5-15. Primers

A primer is sensitive to shock and moisture. A primer should be carefully cleaned and inspected for signs of corrosion and to insure that the seal is firmly in place. Primers will be kept away from propellant bags and left in their sealed containers until ready for use.

5-16. Flash Reducers

Flash reducers are used with white bag (multiforated), separate loading type, propelling charges and are assembled to a particular charge as prescribed in TM 9-1300-203. Because of its hygroscopic qualities, the flash reducer must not be removed from the container

until just before it is to be used. The flash reducer must not be allowed to contact damp ground. Discarded increments should be disposed of in the same manner as discarded igniter pads (para 5-12b).

5-17. Chemical Projectiles (Cartridges)

a. When toxic chemicals are being fired, all personnel should wear protective masks and personnel handling the ammunition should wear gloves. Decontaminating agents should be held in readiness.

b. White phosphorus (WP) projectiles will be stacked vertically and protected from high temperature. If WP projectiles are stacked horizontally in the hot sun, the WP filler (melting point 110° F.) in a projectile may shift to one side of the projectile cavity, resulting in an unbalanced projectile.

5-18. Segregation of Ammunition Lots

Different ammunition lots have different ballistic qualities. Registration corrections derived from firing one lot of ammunition are not necessarily valid for another lot; therefore, it is necessary to segregate the ammunition in the position area by lot. Proper segregation requires control and accounting by the chiefs of sections, recorder, and fire direction center. Each stack of ammunition should have the lot number (or a unit code designation for that number) prominently displayed. As a general rule, the firing of the lot used for a registration is restricted to transfers and missions in which two or more batteries are to mass. In units which fire separate-loading ammunition, both propellants and projectiles must be segregated by lot, and the desired propellant combination must be designated in the initial fire command. When fixed or semifixed ammunition is used, only the lot for the complete round is announced (para 5-10b (6)).

5-19. Replacing Ammunition in Containers

Great care must be exercised in returning ammunition to containers to insure that the ammunition is completely serviceable. Before a round is replaced in its container, a certificate, prepared by an officer of the battery, will be

inserted under the sealing tape used to seal the container so that it will be visible. The certificate will certify that—

a. All increments are present.

b. Increments are serviceable and undamaged.

c. Increments are in proper numerical order.

d. Increments have the same lot number.

e. The lot number of the ammunition is the same as that on the container.

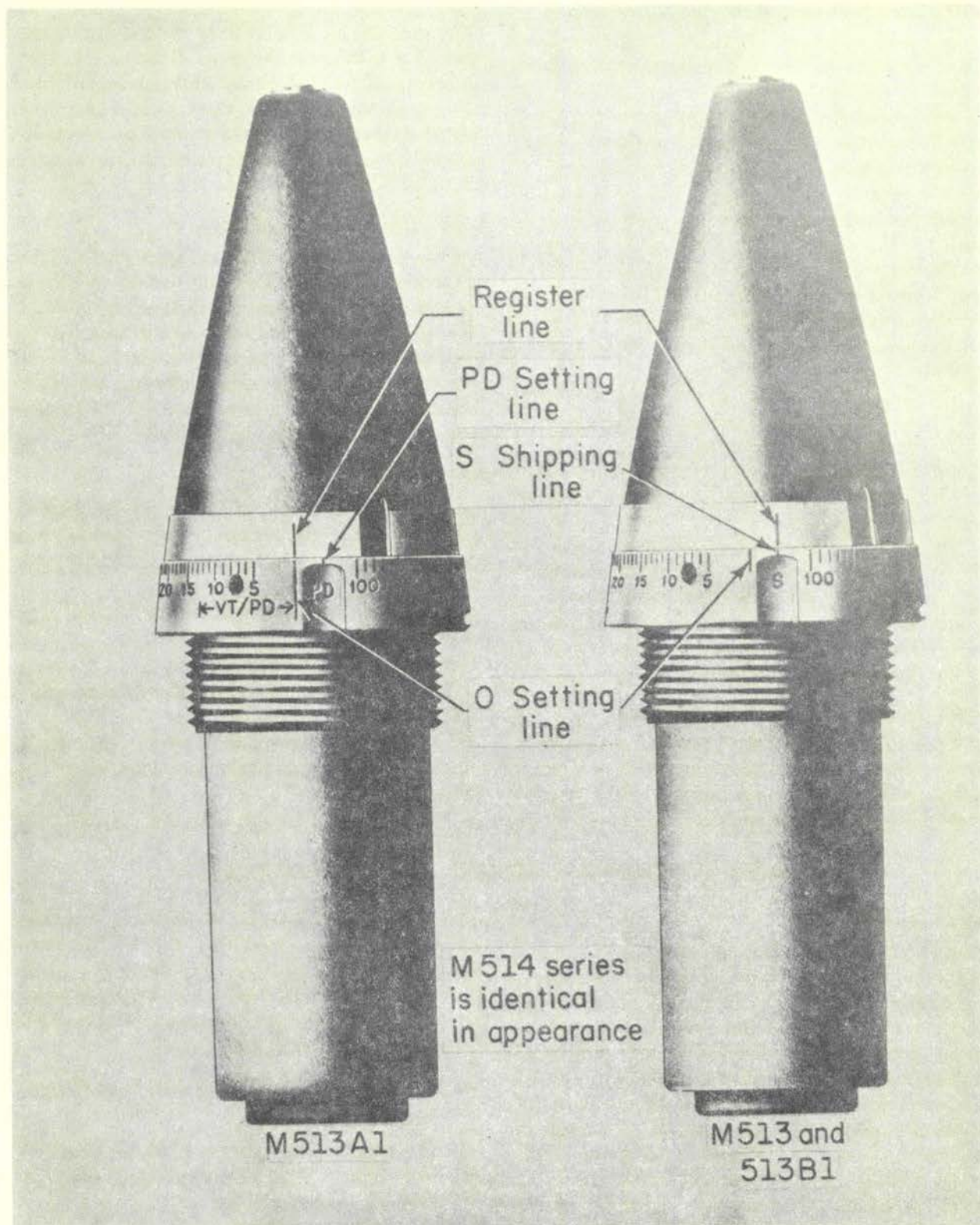


Figure 5-3. M513-series proximity (VT) fuzes

5-20. Data for Computation of Corrections

The executive officer supplies the fire direction center with the following ammunition data for computing corrections:

a. Weight of Projectile. The weight of the projectile is reported as marked on the projectile; e.g., 1 square, 2 square, etc., or (so many) pounds.

b. Propellant Temperature. The propellant temperature reported should be a representative figure for the charges to be fired by the battery, considering variations within stacks and differences between sections. The method of using the propellant thermometer will vary with the type of ammunition. Propellant temperatures are taken as follows:

- (1) *Separate loading.* Insert the thermometer in the end of charge and replace the charge in the container.
- (2) *Semifixed.* Insert the thermometer in the charge and replace the charge in the cartridge case.
- (3) *Fixed.* With fixed ammunition, there is a temperature lag between the inside and outside of the cartridge case. To approximate the propellant temperature, place the cased thermometer inside an empty ammunition container.

5-21. Field Storage of Ammunition

Ammunition at the battery position must be protected from enemy fire and the weather. Only enough ammunition to meet current needs is placed at the pieces. Other ammunition is stored on the

prime movers, on the ammunition vehicles, or, when authorized, at a battery dump. Establishment of a battery ammunition dump is a matter for command decision, because a dump impairs the mobility of the battery. Proper cover reduces the risk of damage by enemy fire and also serves to protect the ammunition from moisture and extremes of temperature.

5-22. Unloading the Piece

When practicable, a loaded piece should be fired rather than unloaded. However, troops should be instructed in the proper method of unloading. They should be assured that unloading can be accomplished safely if the pieces are not overheated and the proper procedures are followed. Details on unloading are contained in the appropriate field manual for the weapon.

5-23. Accidents

AR 700-1300-8 prescribes the method for reporting a premature explosion or other ammunition accidents. The officer in charge at the battery position must—

- a.* See that first aid is rendered to injured personnel.
- b.* Notify his immediate superior.
- c.* Obtain statements from eyewitnesses while details are clearly in mind.
- d.* Preserve all evidence in as nearly the original state as possible until it can be inspected by the ordnance officer.
- e.* Record all data required by AR 700-1300-8.

Section IV. COMMON MISTAKES AND MALPRACTICES

5-24. General

Inaccuracies and waste in artillery fire too often occur from mistakes and malpractices of a recurring nature. A mistake is an unintentional error in action or perception committed while following correct procedure. A mistake usually indicates carelessness or lack of concentration and can be detected only by a positive, independent check or very close supervision. A malpractice is a procedural error and usually indicates incomplete or incorrect training. The best preventive for mistakes and malpractices is the formation of proper habits in training by insisting on exactness and allowing no deviation from correct procedures. A further

preventive for errors to establish in training proper supervisory procedures for the executive officer, chief of firing battery, and chiefs of sections so that all errors are detected and corrected prior to firing. This section is a tabulation of some of the more common firing battery errors.

5-25. Preparation for Firing and Execution of Fire Commands

a. Common Mistakes. Some of the common mistakes made by personnel of the firing battery in executing fire commands are—

- (1) Firing a wrong charge.
- (2) Missetting the fuze, especially by reading

in the wrong direction from numbered graduation.

- (3) Lifting a timed fuze projectile with the hand around the fuze, thereby disturbing the fuze setting.
- (4) Making a 100-mil error in deflection or quadrant elevation.
- (5) Moving in the wrong direction from numbered graduations on the micrometer scales.
- (6) Reading the wrong colored figures on the 10-mil micrometer of the gunner's quadrant.
- (7) Leveling the gunner's quadrant in the wrong direction or using the wrong base, especially in high-angle fire.
- (8) Laying on the wrong aiming posts, especially at night or when there is little lateral interval between pieces.
- (9) Failing to take up lost motion correctly.
- (10) Failing to center all bubbles.

b. Malpractices. Malpractices which may result in serious accidents are—

- (1) Attaching lanyards on 105-mm howitzers directly to the trigger shaft rather than to the firing shaft bracket assembly. This permits firing the weapon before it has returned to battery, resulting in damage to the recoil mechanism and carriage and possible injury to the loader from the recoil.
- (2) Inserting the trigger shaft to test the functioning of the M13 firing lock of the 105-mm howitzer. The practice breaks the lugs forming the T on the end of the firing pin holder.
- (3) Attempting to gain greater ranges by firing propellant charges other than those authorized by firing tables. This results in excessive heat and chamber pressures which cause metal fatigue.
- (4) Loading of the 155-mm howitzer without using the tray which may result in burred breech threads, damaged rotating bands, and improper seating, causing erratic fires.
- (5) Removing the safety latch firing mechanism plunger on the M114A1 or the follower assembly on the M109 so that the firing mechanism and primer can be in-

serted prior to closing the breech. This practice may result in blown breechblocks and housings.

- (6) Exceeding the maximum rates of fire, thus causing the gun tubes to become extremely hot. Projectiles, cool from having been stored in the open, may crack when placed in the hot gun tubes, permitting the filler to melt and run out of the cracks into the powder chamber making an explosion likely. If fired, the broken projectile endangers friendly troops. When the maximum rate of fire is exceeded, the recoil mechanism also becomes extremely hot. This causes a marked increase in pressure within the recoil system which may, in turn, damage the system.
- (7) Digging gun pits in such a manner that the bottom of the pit slopes upward toward the rear. A weapon emplaced in such a pit will be tilted forward; this will reduce the maximum elevation attainable by the weapon and may restrict the firing of high-angle fire.

5-26. Aiming Circle

Some of the errors made by the firing battery personnel in using the aiming circle are—

- a.* Failing to clamp the vertical shaft securely (M1 only).
- b.* Failing to clamp the instrument fixing screw securely.
- c.* Turning the telescope with the wrong motion when sighting through the eyepiece; i.e., using the upper motion instead of the lower motion.
- d.* Failing to level the longitudinal bubble before reading angles of site (M1 only).
- e.* Failing to determine and apply the vertical angle correction to measured angles of site.
- f.* Having objects containing magnetic metals on the person, especially eyeglasses.
- g.* Making a 100-mil error in setting by failing to note that turning the azimuth micrometer has moved the azimuth index to the wrong hundred or setting; for example, 3,697 instead of 3,597 because the azimuth index is near 36.
- h.* Failing to take up lost motion correctly.
- i.* Failing to set up the tripod with one leg pointing in the approximate direction of sighting.
- j.* Failing to set up the instrument the prescribed distance from the nearest piece.

5-27. Miscellaneous

Some of the miscellaneous errors made by the firing battery personnel are—

- a.* Failing to check boresighting in the firing position.
- b.* Improper placing of the thermometer in the propellant.
- c.* Setting aside one specific case or propellant

for propellant temperature control for too long a period of time.

- d.* Firing rounds from oily tubes.
- e.* Failing to set the near aiming post one-half the distance to the far aiming post.
- f.* Lining up the lead line on the wrong side of the vertical hairline with the number displayed in the collimator.

CHAPTER 6

FIRING WITHOUT A FIRING CHART

6-1. Introduction

a. A field artillery battery must be able to deliver timely fire even though a fire direction center is not available to produce firing data. There are numerous solutions for converting the observer's call for fire to fire commands without a complete set of fire direction equipment and a firing chart. This chapter presents a solution that is simple and rapid.

b. Actions that must be taken to fire without a firing chart fall into three phases—

- (1) Determination of data with which to fire the initial round(s).
- (2) Conversion of the subsequent corrections announced by the observer with respect to the observer-target (OT) line to corrections (in meters) with respect to the gun-target (GT) line.
- (3) Determination of firing data.

6-2. Occupation of Position

The firing battery occupies position and is laid by using the procedures described in paragraphs 4-1 through 4-8. The azimuth on which the executive officer should lay the battery is determined from a knowledge of the situation and reference to a map (if available).

6-3. Determination of Firing Data for Initial Round(s)

Firing data for initial round(s) are determined as follows:

a. The observer sends the call for fire, following the procedures described in chapter 9. The target may be located by any of the methods described in chapter 8.

b. On receipt of the call for fire, the executive officer must determine the direction and range to the target.

- (1) The executive officer may estimate the direction (azimuth) and range based upon his knowledge of the situation.
- (2) The executive officer may measure direction (azimuth) and range from a map, if available.

c. Deflection is determined by comparing the azimuth to the target and the azimuth on which the battery was initially laid and applying the difference to the referred deflection at which the aiming posts were placed.

d. Site can be ignored unless the map (if available) indicates a large difference in altitude between the battery position and the target.

e. Elevation can be determined from either a tabular firing table (TFT) or a graphical firing table (GFT).

f. Initial fire commands are given in the prescribed manner (para 4-28-4-49).

6-4. Determination of Angle "T"

a. The angle τ is computed by comparing the observer-target direction from the observer's call for fire and the azimuth from the battery position to the target determined in paragraph 6-3*b*. Comparing the two will also give the relative location (right or left) of the observer with respect to the battery.

b. The M10 plotting board is prepared for use during the adjustment by placing a mark on the rotating disk opposite the number representing the angle τ . If the observer is to the right of the battery, the black numbers to the right of the 0-0-32 are used; if the observer is on the left, the red numbers to the left of the 0-0-32 are used. By rotating the disk until the value of angle τ is opposite the red zero on the vernier of the plotting board, a graphical representation of the OT-GT line relationship is obtained. The centerline of the rotating disk represents the OT line. The centerline of the plotting board represents the GT line (fig. 6-1).

c. The angle τ determined initially is retained throughout the mission unless the weapons shift more than 200 mils from the deflection fired on the initial round.

6-5. Conversion of Observer's Subsequent Corrections to Corrections With Respect to the Gun-Target Line

a. During the adjustment, the observer follows normal observer procedures.

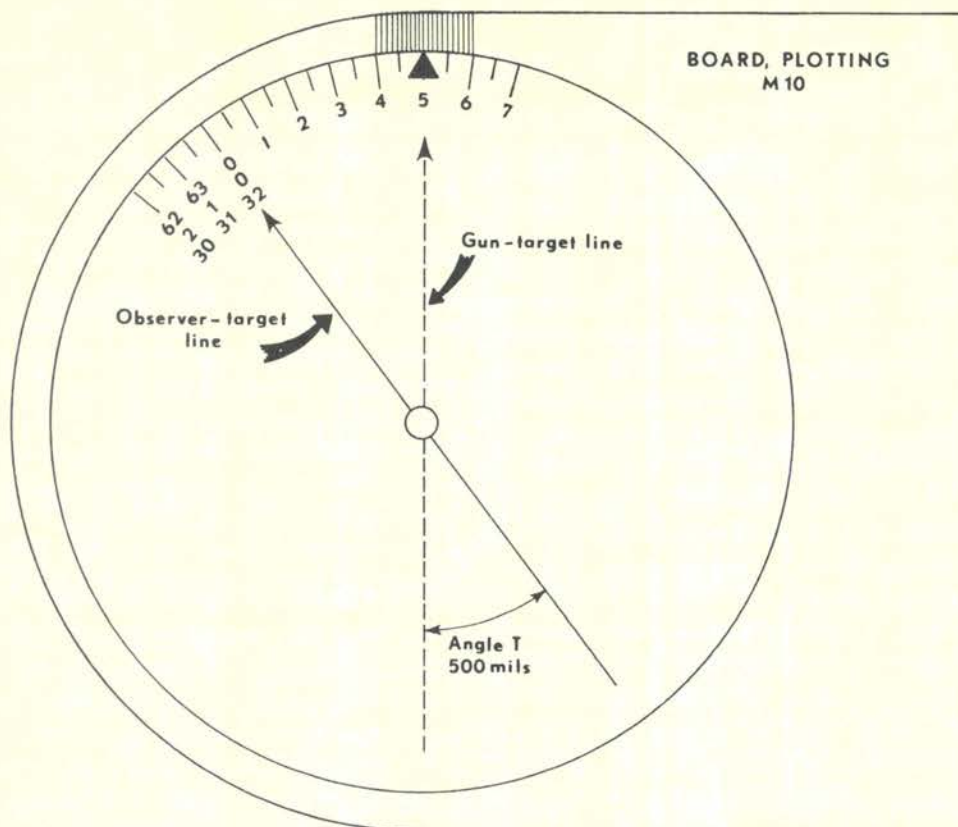


Figure 6-1. Angle τ position.

b. The observer's shifts are converted to corrections with respect to the GT line, using the M10 plotting board.

- (1) The center of the plotting board always represents the location of the last burst.
- (2) The rotating disk is zeroed (i.e., the 0-0-32, or arrowhead, on the centerline is placed opposite the red 0 on the vernier) and the observer's shift is plotted on the disk, using the grid on the plotting board and any convenient scale. Most shifts can be plotted when a value of 10 or 20 meters is assigned to each small square.

Example: Angle τ is 500 mils; observer is to the right of the battery. The observer's shift is RIGHT 120, DROP 400. With the disk zeroed and each small square representing 20 meters, the shift is plotted, using pencil mark, 6 small squares to the right and 20 small squares toward the bottom of the board from the center (fig. 6-2).

- (3) The disk is now rotated until the value of the angle τ is opposite the 0 on the vernier. As the disk is rotated, the plot of the

observer's shift with respect to the OT line is unchanged. When the angle τ is set off, the shift with respect to the GT line (centerline of board) can be measured from the center of the board.

Example: Continuing the example in (2) above, the 500-mil mark is placed opposite the 0 on the vernier. The shift from the center of the board to the plotted point on the disk can now be measured with respect to the centerline of the board (GT line) as RIGHT 290, DROP 300. This shift is in meters (fig. 6-3).

6-6. Determination of Firing Data for Subsequent Rounds

a. *Deflection.* To determine the deflection, it is necessary to convert the deviation corrections (in meters) with respect to the GT line to mils and apply the correction in mils to the previously fired deflection. To convert deviation in meters to deviation in mils, it is necessary to multiply the 100/R value for the range to the target by the meter deviation divided by 100. The 100/R value can be

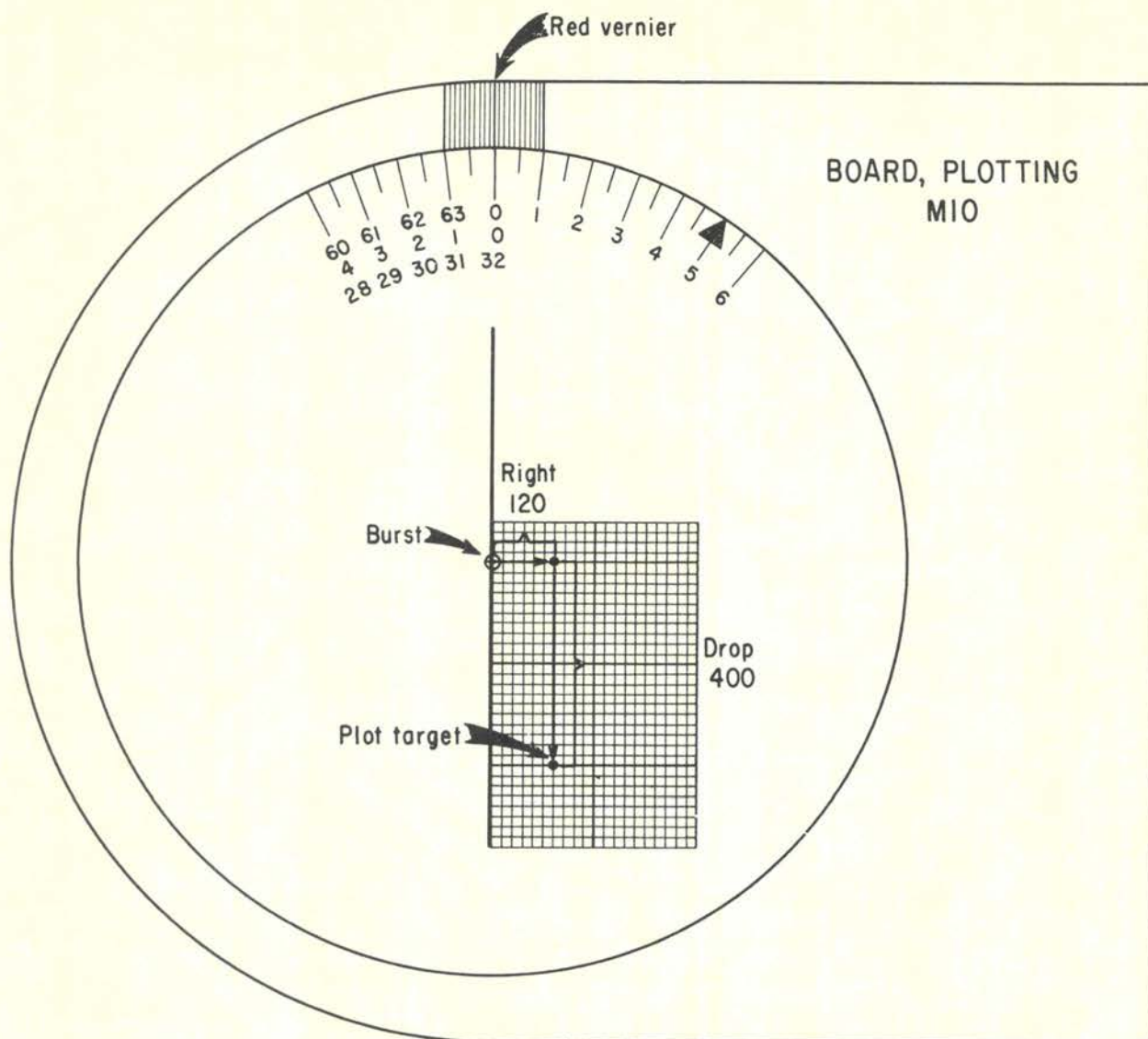


Figure 6-2. Original position.

computed (100 divided by the range in thousands of meters) or read from the GFT under the hairline, when the hairline is set over the range. Continuing the example in paragraph 6-5, the $100/R$ is determined to be 20 mils. The observer's subsequent correction was converted to the GT line, and a deviation correction, in meters, of RIGHT 290 was determined. The deviation in mils is computed to be RIGHT 58,

$$\frac{(290 \times 20)}{100}$$

The deflection announced to the weapons is DEFLECTION 3142 ($3200 + R58$) or ($3200 - 58$).

b. Elevation. Elevation is determined by one of the following methods:

- (1) *Graphical firing table.* When a graphical firing table is used, the hairline of the cursor is moved from the last range fired an amount equal to the range correction along the GT line, and a new elevation is read under the hairline (elevation gage-line, if any).
- (2) *Tabular firing tables.* When a tabular firing table is used, the C (change in elevation for a 100-meter change in range) is determined at the initial range and used

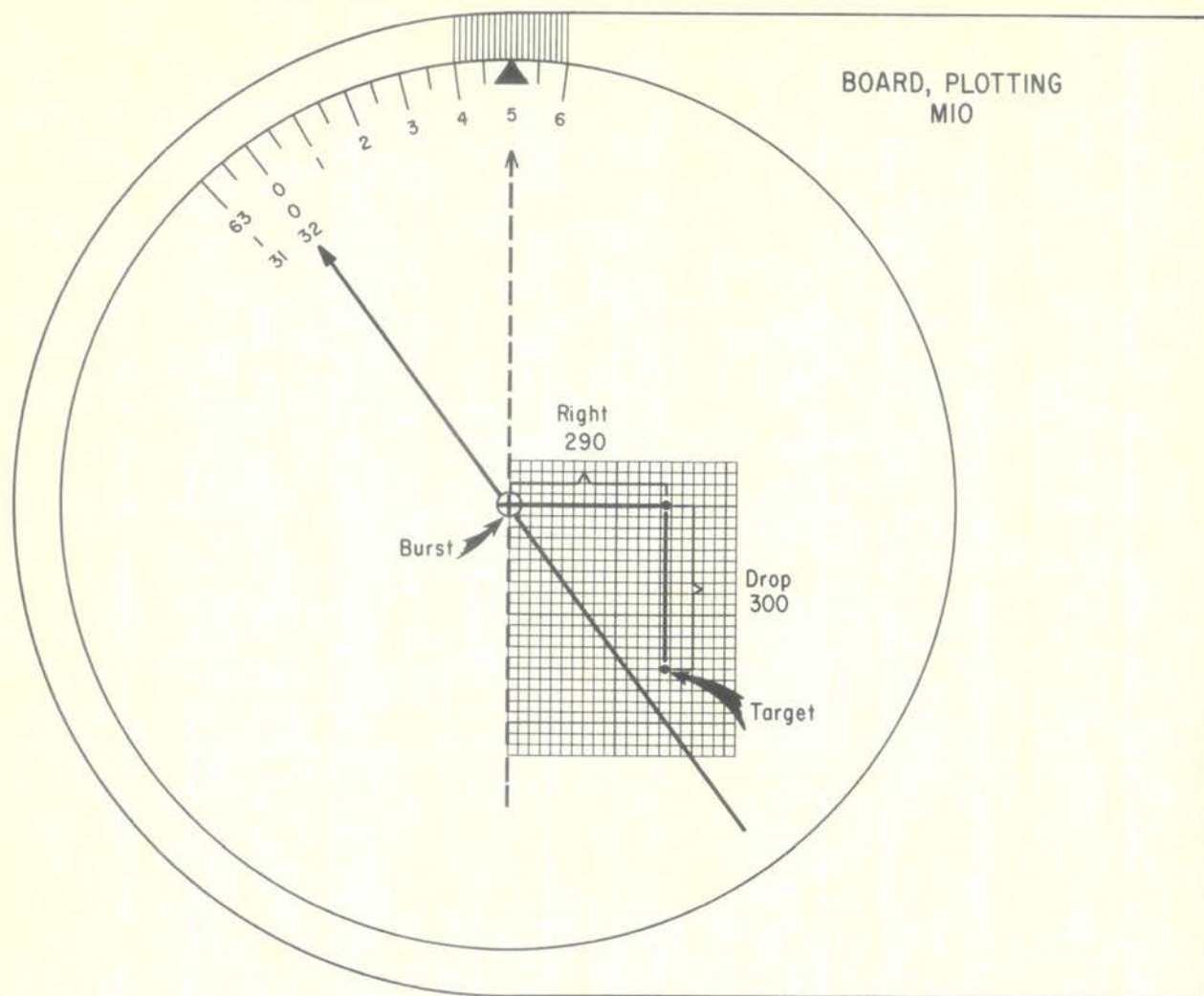


Figure 6-3. Determining corrections with respect to gun-target line.

throughout the mission. The *C* used is the tabular value rounded off to the nearest whole mil. When the range correction along the GT line has been determined, an elevation change is computed by multiplying the *C* by the range change divided by 100. The elevation change is then applied to the last elevation fired in order to determine the elevation for the next round.

Example: Weapon, 155-mm howitzer M109, charge 5 green bag, initial range 5200, initial elevation 247. *C* is determined to be 6 mils. The range change with respect to the GT line is determined to be DROP 300. The elevation change is computed to be -18 mils ($300/100 = 3 \times 6$). The elevation for the next round is 229 ($247 - 18$).

6-7. Small Angle "T"

When the angle *T* is less than 100 mils, the OT line and the GT line may be considered to be the same. The observer's shifts need not be converted to the GT line but may be converted directly to firing data by using the procedure described in paragraph 6-6.

6-8. Procedure When M10 Plotting Board is Not Available

When the M10 plotting board is not available, the executive officer may direct the observer to adjust with respect to the GT line. The observer's shifts are then converted directly to firing data by using the procedure described in paragraph 6-6.

PART THREE

OBSERVER PROCEDURES

CHAPTER 7

FIELD ARTILLERY OBSERVATION

Section I. INTRODUCTION

7-1. General

a. Field artillery normally is employed in a manner requiring some type of observation. This observation may be visual, it may be electronic, or it may be indirect observation through study of aerial photographs.

b. Electronics devices generally fall into two classes—radar ranging equipment and sound ranging equipment. Employment of these devices is described in FM 6-120, FM 6-121, FM 6-122, FM 6-160, and FM 6-161.

c. Observer procedures discussed in this manual pertain solely to visual observation and include both air and ground observer techniques. Whenever appropriate, these techniques are explained in the light of their relationship to other phases of gunnery, primarily the fire direction phase.

d. Target grid procedures, on which fire direction and observation are based, relieve the observer of many functions normally required of him by other gunnery systems. However, the importance of the observer as a vital member in the gunnery team must be emphasized. The observer is the only member of the gunnery team who can actually see the enemy forces, the friendly forces, and the fires placed on the enemy by all combat arms. His ability to observe and his knowledge of the battle situation must be exploited to assist in keeping his unit adequately informed at all times. Moreover, the observer must know and understand the problems and procedures of the fire direction center. He can then combine this knowledge with his own judgment to effectively assist the gunnery team in fulfilling its purpose.

7-2. Purpose

Observation is employed by artillery for four purposes: target acquisition, adjustment of fires when necessary, surveillance of fire for effect, and battlefield surveillance.

a. Target acquisition is concerned with detecting suitable targets and determining their ground locations. This information is reported to the FDC where it may be used in the production of firing data.

b. Adjustment of fires is necessary to obtain effective fire on the target when the accuracy of battery of target location data is questionable and when current meteorological or registration corrections are not available.

c. Surveillance of fire for effect is a follow-through of target acquisition. Since the observer can see the target, he can direct fire and report its effect to the fire direction center. This report should include an accurate account of damage and any appropriate shifts necessary to make the fire more effective.

d. Battlefield surveillance (intelligence) is a very important byproduct of artillery observation. Observers must report everything which they observe. Information not necessary for the conduct of fire must be reported promptly, but such action must not delay fire missions.

7-3. Duties of the Observer

For a discussion of field artillery observer duties and tactics, see FM 6-20-1 and FM 6-140.

Section II. PREPARATORY OPERATIONS

7-4. General

The observer's preparatory operations contribute to his speed and accuracy in locating targets

and reporting information to the fire direction center.

a. Before occupying an observation post (OP)

or joining the infantry or tank company that he is to support, the observer should—

- (1) Check equipment.
- (2) Report to the proper artillery and infantry (tank) personnel for briefings.
- (3) Brief his section.
- (4) Make a map reconnaissance.
- (5) Check communications.

b. Upon occupying an observation post or joining the infantry (tank) company that he is to support, the observer should—

- (1) Check communications.
- (2) Orient his map and plot those points the locations of which can be determined.
- (3) Report his location and field of observation to the fire direction center.
- (4) Prepare an observed fire (OF) fan.
- (5) Prepare a terrain sketch to supplement the map.
- (6) Prepare calls for fire for points at which targets may appear.

c. A call for fire is not delayed merely to complete preparatory operations.

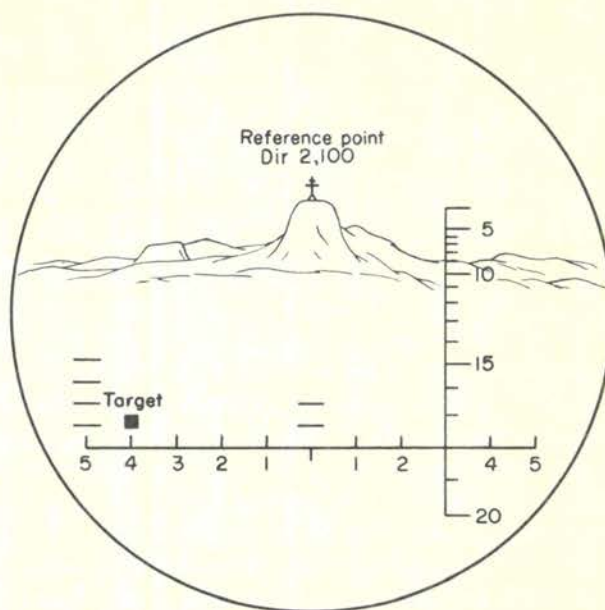
7-5. Orienting for Direction

a. Target grid procedures require that the grid direction from the observer to the target be determined and reported to the fire direction center. The observer should orient himself for direction by determining and recording the grid direction to a number of sharply defined terrain features that he has chosen as reference points.

b. Grid directions normally are measured with a declinated magnetic instrument. Directions may also be measured from a map when the observer's position is known and plotted.

c. After a number of reference point directions have been recorded, the observer can determine the direction (dir) to any other point in the target area by measuring, with the horizontal mil scale in his binoculars, the angle from a reference point to the desired point. In figure 7-1, the target is 40 mils left of the reference point. Direction to the target is 2,060 mils (2,100-40).

d. The tank-mounted observer is faced with a special problem in determining direction because magnetic instruments will not function properly in a tank. If the tank is stationary and the observer knows his location, direction can be measured from a map; but if the tank is moving, the



Vertical scale on right of lens is not used by the FO in determining data for his call for fire. It is used primarily by the Infantry for siting automatic weapons.

Figure 7-1. Use of reference point direction and binocular scales to determine direction to target

problem can be solved by using the gun-target line, a prominent terrain feature, or a cardinal direction.

7-6. Location of Known Points

To facilitate the location of targets, the observer and FDC select points in the target area which can be identified by the observer and which are plotted on the firing chart. The location of the *known points* may be determined from maps, by survey, or by firing.

7-7. Location of the Firing Battery

Although target grid procedures do not require that the observer know the location of the battery which is firing his mission, knowledge of the location will give the observer a greater appreciation of the effects he observes.

7-8. Auxiliary Map Data

a. When the observer has completed his initial orientation, he begins a systematic augmentation of map data. This augmentation consists principally of recording information on his map and pre-

paring a terrain sketch. As time permits, he also prepares a visibility diagram.

b. The map is augmented with lines of direction radiating from the observer's position at convenient angular intervals. These lines are intersected with arcs of distance by using the observer's position as the center (fig. 7-2). The observer then marks points of importance which were not included on the map when printed. He also marks any points which he might frequently need, such as reference points, registration points, targets, and likely points of enemy activity.

c. An observed fire (OF) fan may be used instead of marking a map as in *b* above. The observed fire fan (fig. 7-3) is a fan-shaped protractor constructed of transparent material, covering a 1,600-mil sector. This fan is divided by radial lines 100 mils apart. Arcs representing distances from the OP are printed on the fan in increments of 500 meters from 1,000 to 6,000 meters. To use the OF fan, the observer orients the fan on his map with the vertex on his OP location, the fan centered approximately on the zone of observation, and one of the radial lines parallel to a grid line or other line of known direction. The fan is then taped or tacked to the map. The line of known direction is

labeled with its correct direction, and the other radial lines are then labeled with their directions. If desired, only the 200-mil direction lines are labeled.

d. Another device which the observer uses to assist in the location of targets is the terrain sketch (fig. 7-4). The terrain sketch is a panoramic representation of the terrain, sketched by the observer, showing reference points, registration points, targets, and points of probable activity. The terrain sketch is also a rapid means of orienting relief personnel.

e. When available, photographs of the area of observation should be marked, showing pertinent points and lines of direction, and used in conjunction with the terrain sketch. Copies of the photograph and the terrain sketch may be required for reference at the fire direction center.

f. The visibility diagram (fig. 7-5) is a sketch of the area of observation, drawn to map scale, showing those portions which cannot be observed from a given observation post. This diagram may be prepared by observer personnel or by FDC personnel if the position of the observation post is plotted on FDC maps.

- (1) When the observer prepares the visibility diagram, a copy on overlay paper is sent to the fire direction center. The diagram is prepared by constructing profiles of the terrain along radial lines emanating from the observation post (FM 21-26). Each adjacent pair of rays should form an angle no greater than 100 mils. When the profile along each ray is completed, straight lines are drawn from the observer's position to each point of high ground in the field of observation. These rays represent lines of vision; all ground areas between a peak point of tangency and the intersection of a ray with the ground are blindspots (fig. 7-6). These blindspots are projected to the base of the diagram and transferred to the appropriate line of direction on the observer's map or on a piece of overlay paper. Related points are connected and blind areas are shaded (fig. 7-5).
- (2) Use of visibility diagrams will reduce the chance of observer error in reporting tar-

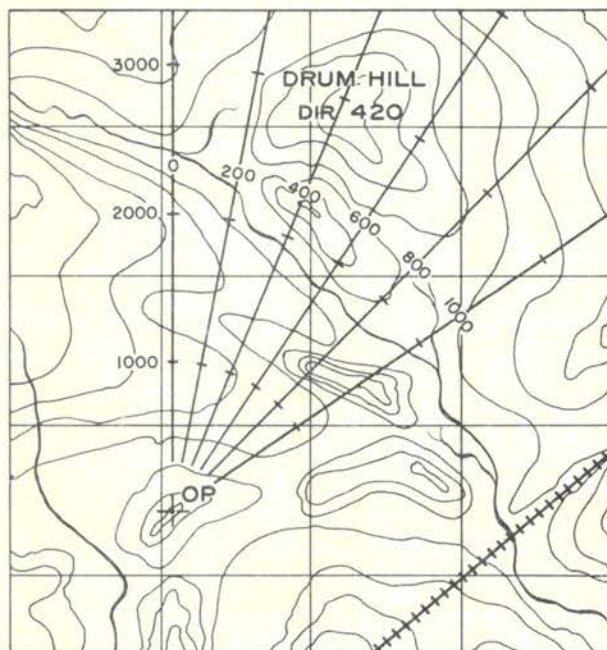


Figure 7-2. Map augmented to show lines of direction and distance from the observer position

get locations. If the target is plotted in an area which is not visible, the location data are obviously in error. The diagram

aids the S2 in evaluating target area coverage and in determining the best locations for additional observation posts.

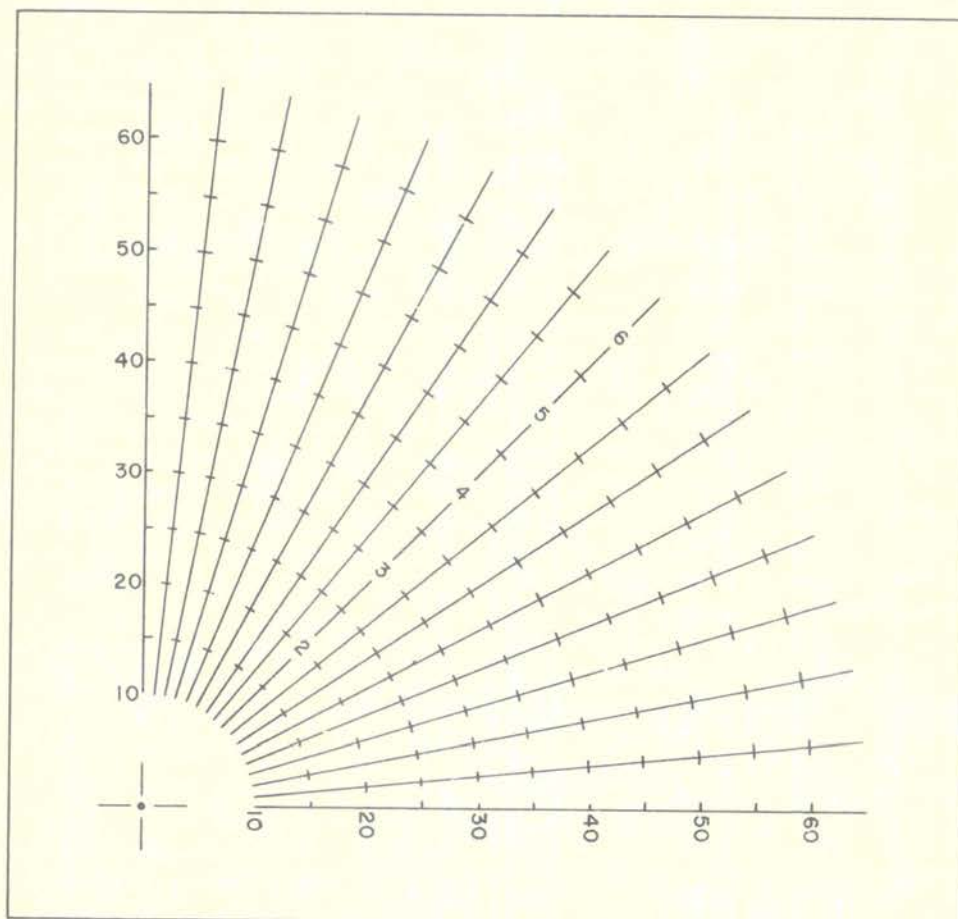


Figure 7-3. The observed fire fan

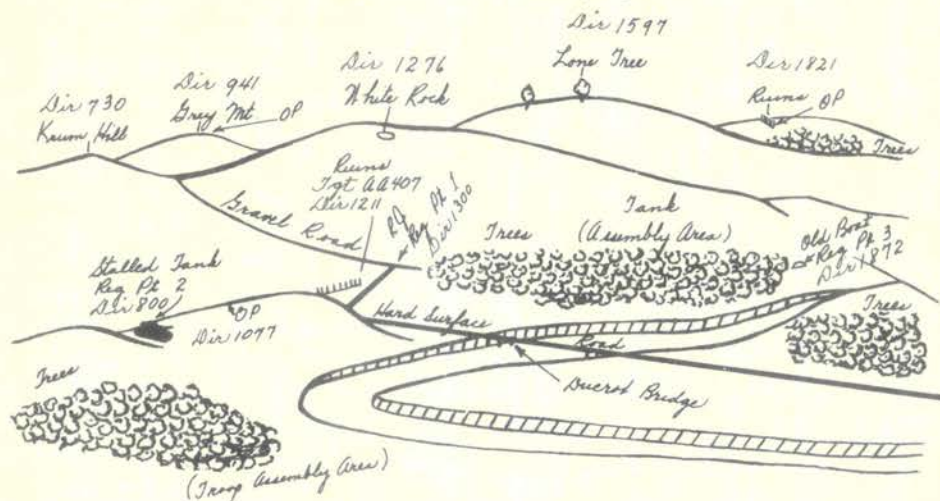


Figure 7-4. Terrain sketch

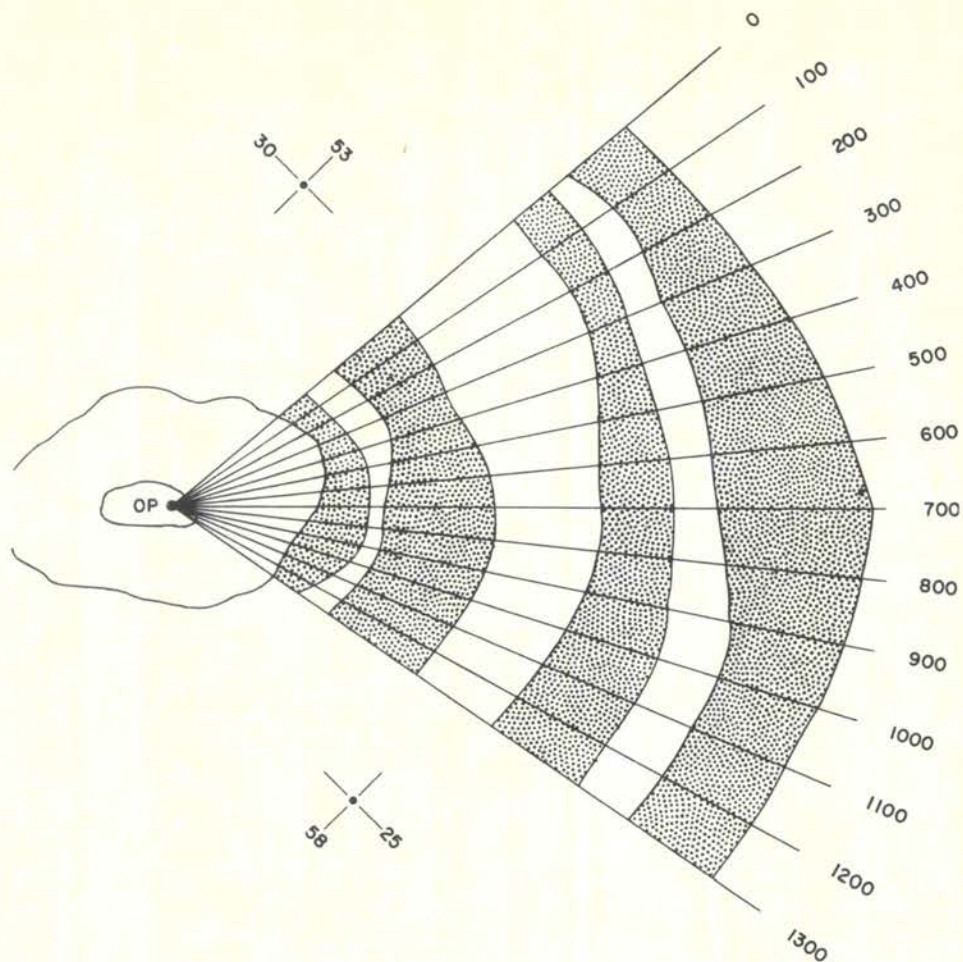


Figure 7-5. Construction of visibility diagram using direction rays

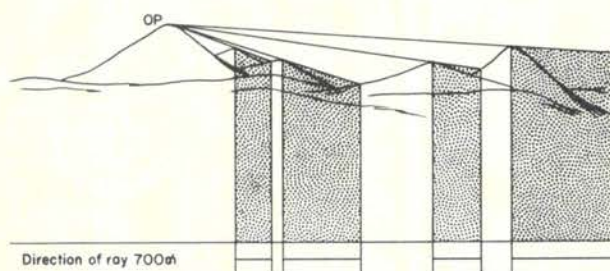


Figure 7-6. Use of profile to show blindspots (shaded areas)

CHAPTER 8

LOCATION OF TARGETS

8-1. General

The most accurate means available are employed in locating targets and determining initial data in order to insure safety to friendly troops, to save ammunition, to save time in adjustment, and to increase effectiveness of fire. This initial accuracy is obtained by using data from all previous firing in the area as well as maps, photographs, diagrams, or panoramic sketches of the area. The preparatory operations discussed in chapter 7 are desirable and necessary; however, failure to complete them on occupation of an observation post will not preclude the observer calling for fire as soon as targets are observed. Firing often begins before the preparatory phase is completed; and the firing may be precision fire, which places fire on a specific point, or area fire, which covers a given area with fire. With either precision or area fire, the observer processes the call for fire through the FDC by using a standard sequence and procedure. The sequence is as follows:

- a. Target location.
- b. Preparation and submission of a call for fire.
- c. Adjustment of fire, if necessary.
- d. Surveillance of fire for effect.

8-2. Target Location

a. *Methods.* The following three methods are used by the observer in designating the location of targets so that FDC personnel may plot them on their charts:

- (1) Grid coordinates (para 8-5).
- (2) Reference to a point of known location (para 8-6).
- (3) Polar coordinates (para 8-7).

b. *Accuracies and Announcement of Data.* All data for target locations in calls for fire and subsequent corrections are determined to an accuracy consistent with the equipment used for determination. The observer will normally round off and announce his data as follows:

- (1) Direction to nearest 10 mils.
- (2) Deviation to nearest 10 meters.
- (3) Vertical change to nearest 5 meters.
- (4) Range to nearest 100 meters.
- (5) Grid coordinates to nearest 10 meters.

8-3. Determination of Distance

The observer must be able to determine quickly and accurately the distance between objects, targets, or bursts in order to determine basic data and to adjust artillery fire effectively. Distances can be determined by estimation or computation.

a. *Estimation of Distance.* Estimation of distance is facilitated by establishing a yardstick on the ground in the target area. This yardstick can be established by firing from the same piece or platoon ranging rounds that are 400 meters apart in range. The observer can also establish a known distance in the target area by determining from his map or photograph the distance between two points which he can identify positively both on the map and on the ground. The approximate distance from the observer to a sound source (bursting shell, weapon firing, etc.) can be estimated by timing sound. (Speed of sound in still air at 59° F. is approximately 340 meters per second. Wind and variation in temperature alter this speed somewhat.) For practical use by the observer, the speed of sound may be taken as 350 meters per second under all conditions. The sound can be timed with a watch or by counting from the time a burst or flash appears until the sound is heard by the observer. For example, the observer counts "one 1,000, two 1,000," etc., to determine the approximate time in seconds. The time in seconds is multiplied by 350 to obtain the approximate distance in meters.

Example: The observer desires to determine the approximate distance from his position to a burst. He begins counting when the burst appears and stops counting when he hears the sound. He counted 4 seconds; therefore, the burst was approximately 1,400 meters (350×4) from his position.

b. *Computation of Distance.* Distance may be computed by using the angle measured from one point to another and the known lateral distance between the two points. The distance from the observer may be computed by applying the mil relation formula. The mil relation formula is based on the assumption that an angle of 1 mil will subtend a width of 1 meter at a distance of 1,000

meters. The formula is expressed as $m = \frac{W}{R}$, where

m is the angular measurement in mils between the two points, R is the distance in thousands of meters (expressed to the nearest 100) to the known point, and W is the width in meters between the points from which angle m was measured (fig. 8-1).

Example: An observer measures an angle of 5 mils between the ends of a flat car which is 16 meters long. The distance from the observer to the flat car is determined by substituting in the formula $R = \frac{W}{m}$ ($R = \frac{16}{5} = 3.2$). The distance is 3,200 meters.

8-4. Measurement of Angles

An observer usually uses some angle-measuring device, such as fieldglasses, an aiming circle, or a battery commander's telescope (BC scope), to measure angles. When instruments are not available, angles can be measured by using the hand and finger held at a fixed distance from the eye. The specific angle subtended by the hand in various attitudes must be determined by the individual before he goes into the field and must be recorded and memorized for rapid use (fig. 8-2).

8-5. Target Location by Grid Coordinates

a. Auxiliary map data greatly simplifies the

determination of accurate grid coordinates of a target. When the observer sees a target that is located where it cannot be plotted by rapid inspection, he must first determine the target direction. He determines the direction by using any of the methods described in paragraph 7-5.

b. After the observer has determined the direction and his location, he refers to the corresponding line of direction on the map (or observed fire fan). He selects the point on this line which best describes the target location. He may locate this point by comparing map features with ground features or by estimating the distance from his position to the target. In figure 8-3, the observer has measured a direction of 680 mils to a target which is located on a small hill an estimated 3,000 meters from the observer's location. He has pin-

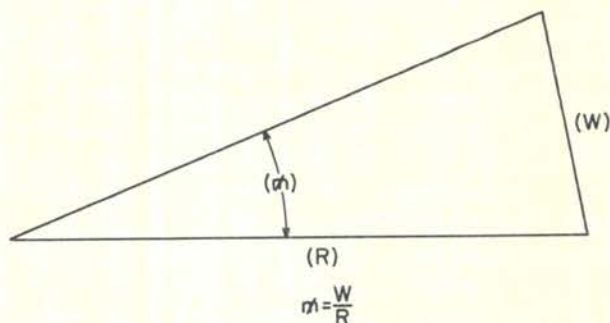


Figure 8-1. The mil relation

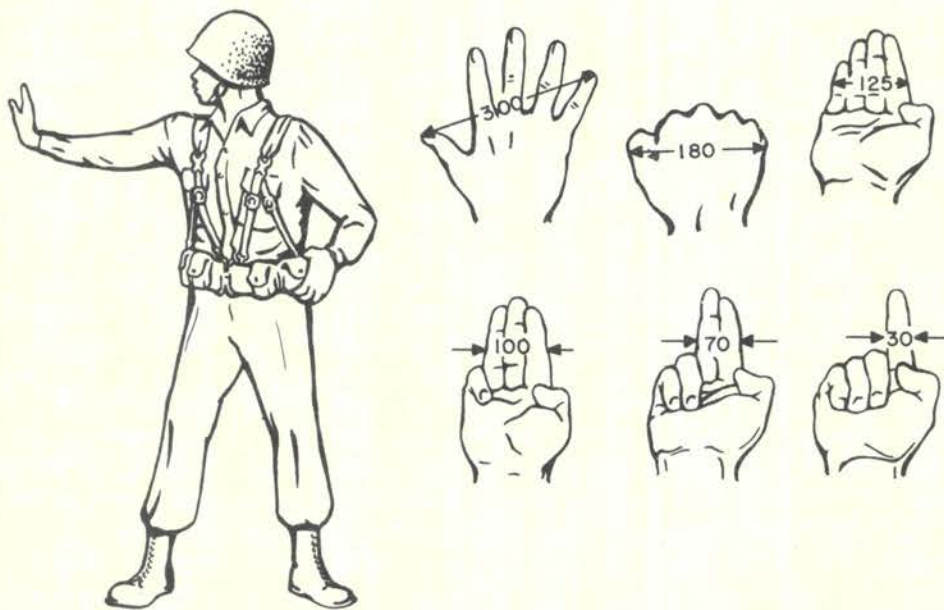


Figure 8-2. Examples of measuring angles with the hand

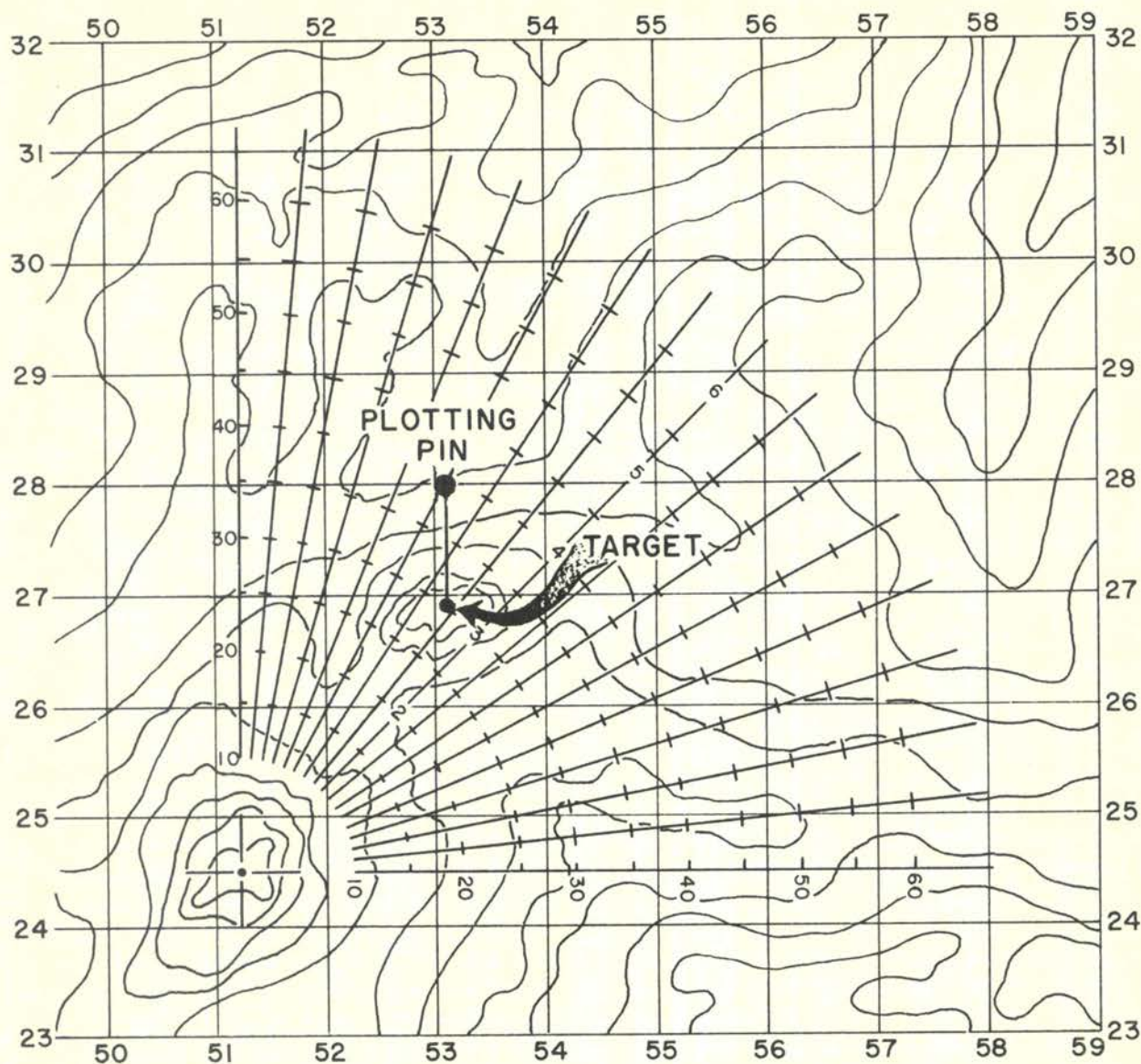


Figure 8-3. Use of observed fire fan to assist in reading coordinates

pointed the target on the map by plotting a distance equivalent to approximately 3,000 meters along a ray corresponding to direction 680 mils on the observed fire fan. A study of the contour lines aids the observer in estimating the range more accurately.

c. After the observer has located the target on the map, he marks the location and determines the grid coordinates with a coordinate scale or by estimation. When properly used, the coordinate scale enables the observer to measure both easting (E) and northing (N) coordinates with one

placement of the scale. To measure the coordinates of a target, the observer first determines the grid coordinates of the lower left-hand corner of the grid square containing the target. Starting at this grid intersection, he slides the coordinate scale to the right, keeping the horizontal scale in coincidence with the E-W grid line, until the target is reached by the vertical scale. He then reads the distance east and the distance north from the scale (fig. 8-4) and adds these readings to the coordinates of the grid square to obtain the coordinates of the target; i.e., 53152475.

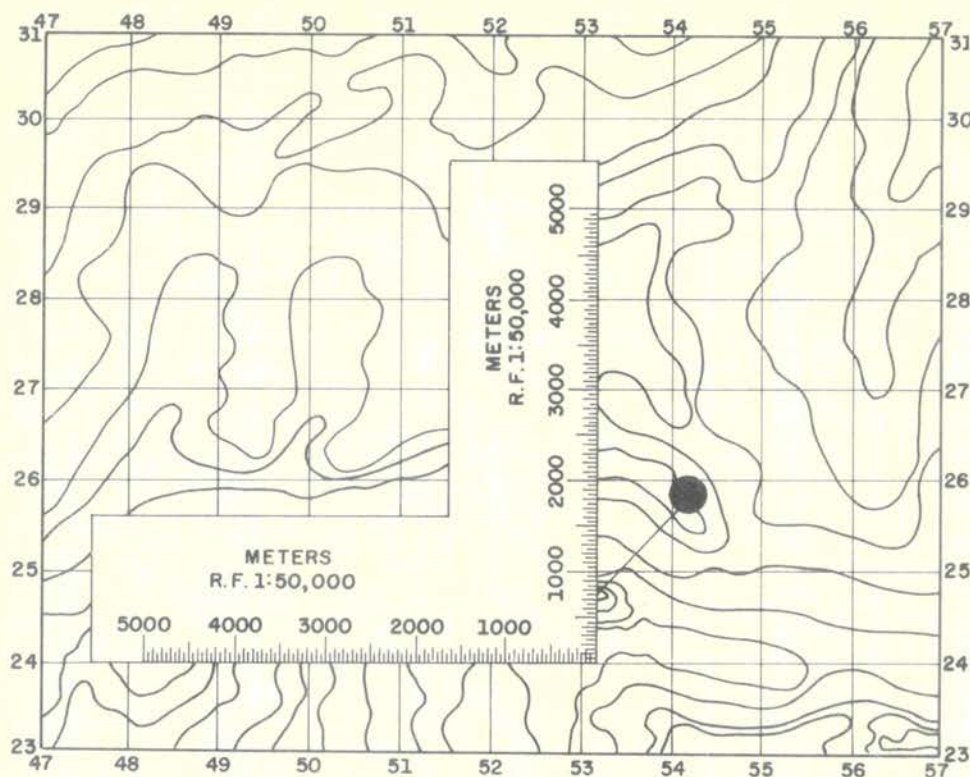


Figure 8-4. Use of coordinate scale

d. Grid coordinates may also be determined by relating the target location to one of several ground features marked on the map. This system should be used with extreme care, especially in deceptive terrain, unless the location is such as to preclude error (road junction, building, bridge, etc.). A rapid check of the accuracy of the coordinates can be made by use of the contour lines on the map. If the plotted altitude of a target shows marked disagreement with the actual ground conformation, the target should be replotted.

8-6. Target Location by Shift From a Known Point

In order to locate a target by a shift from a known point, FDC personnel must have the location of the known point plotted on their charts. Either the observer or the S3 may select points for use as known points, but both the observer and FDC personnel must know their locations and designations. Registration points, prominent terrain features, and previously fired targets are commonly used as known points. To locate a target by a shift from a known point, the observer must de-

termine the observer-target direction, a horizontal shift, and a vertical shift.

a. *Observer-Target Direction.* The observer-target (OT) direction is normally determined by measuring the angular deviation from a reference point to the target and applying the measured deviation to the direction from the observer to the reference point. The measured deviation is added if the target is to the right of the reference point and subtracted if the target is to the left of the reference point. Observer-target direction may also be measured with a properly declinated magnetic instrument.

b. *Horizontal Shift.* The horizontal shift (fig. 8-5) from a known point to the target consists of a lateral shift in meters and a shift in range along the OT line. The lateral shift is made from the known point along a line perpendicular to the OT line at the point (T') at which the perpendicular intersects the OT line. The shifts are plotted in the FDC on a target grid oriented on the OT direction. The method used by the observer to compute the horizontal shift depends on the size of the angular deviation measured from the known point to the target.

- (1) *Deviation of less than 600 mils.* When the angular deviation from a known point to the target is less than 600 mils, the mil relation formula (para 8-3b) is used to compute the lateral shift. The shift in range is determined by comparing the distance from the observer to the known point to the distance from the observer to the target.

Example: An observer measures an angular deviation from registration point 1 to the target of right 250 mils. He knows the distance to registration point 1 to be 3,200 meters and estimates the distance to the target to be 3,700 meters (fig. 8-5). The lateral shift is determined by substituting in the formula $W = R\phi$ ($W = 3.2 \times 250$, or right 800 meters). The range shift is add 500 ($3700 - 3200 = 500$ meters). The shift is announced as RIGHT 800, ADD 500.

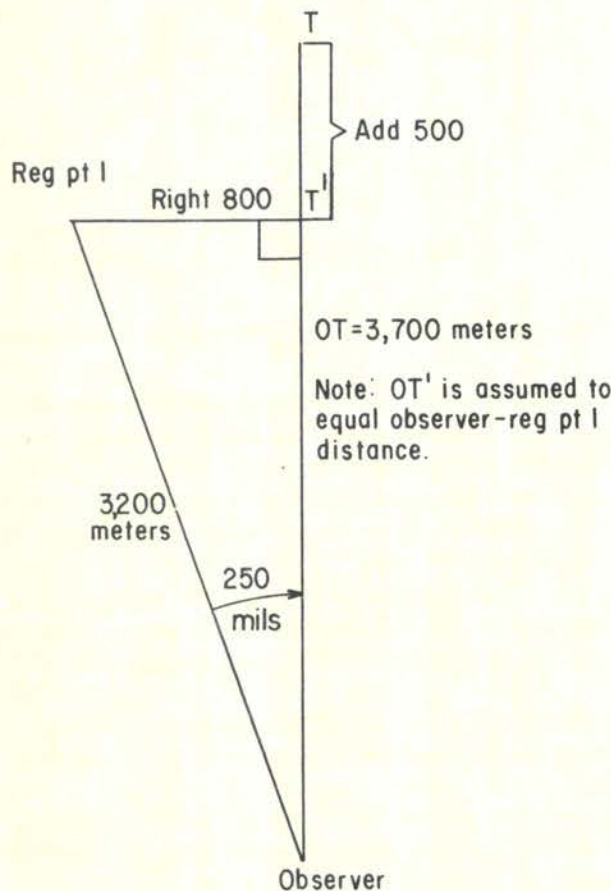


Figure 8-5. Computation of lateral and range shift

- (2) *Deviation of 600 mils or greater.* When the angular deviation from a known point to the target is 600 mils or greater, the mil relation formula for computing the lateral shift is no longer valid, and a trigonometric function must be used to determine the horizontal shift. A trigonometric function is the ratio between two sides of a right triangle. One of these trigonometric functions is the sine (sin). In figure 8-6, the sine of angle A is the length of the side opposite angle A divided by the length of the hypotenuse. The formula for use of the sine factor is $F = \frac{W}{D}$, where F is the sine factor

for the angular deviation ϕ (value taken to the nearest 100 mils), D is the distance to the reference point (hypotenuse), and W is the width of the side opposite the angle ϕ . Note that D , or distance, is not reduced to units of thousands of meters when sine factors are used. The sine factors are as follows:

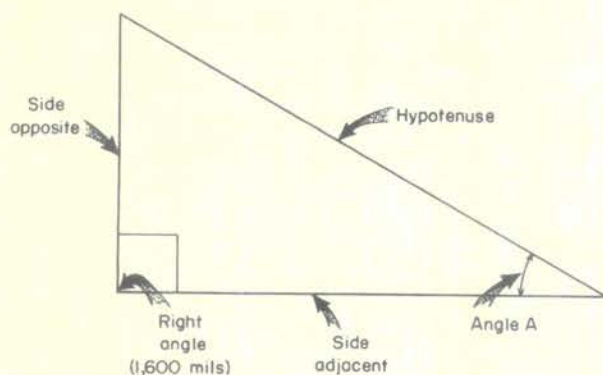
Angle in mils	Sine factor
100	0.1
200	.2
500	.3
400	.4
500	.5
600	.6
700	.6
800	.7
900	.8
1000	.8
1100	.9
1200	.9
1300	1.0
1400	1.0
1500	1.0
1600	1.0

The lateral shift is computed by substituting in the formula $W = F \times D$ where F is the sine factor of the angular deviation from a known point to the target and D is the distance (to the nearest 100 meters) to the known point. To determine the range shift, it is first necessary to determine the distance from the observer to the point at which a perpendicular from the known point to the OT line strikes the OT line (T'). This is accomplished

by substituting again in the formula $W = F \times D$ where, this time, F is the sine factor of the angle complementary to the angular deviation and D is, again, the distance from the observer to the known point. The range shift is determined by comparing the OT' distance and the observer-target (OT) distance.

Example: An observer measures the angular deviation from registration point 1 to the target as left 700 mils. The distance from the observer to registration point 1 is 2,500 meters, and the estimated distance from the observer to the target is 3,100 meters (fig. 8-7).

Solution: Lateral shift, or W , = 0.6 (sine factor for 700 mils) $\times$ 2,500, or left 1500. OT' , or W , = 0.8 (sine factor for 900 mils) $\times$ 2,500 = 2,000 meters. Range shift is ADD 1100 (meters).



$$\text{Sine of angle A} = \frac{\text{side opposite}}{\text{hypotenuse}}$$

Figure 8-6. Sine function

c. *Vertical Shift.* When the shift from a known point method is used, a vertical shift must be made if there is an obvious difference in the altitude of the known point and the target. The vertical shift is normally estimated; however, it may be computed if an angle-measuring instrument (M2 compass, aiming circle, or BC scope) is available. The following procedure is used to compute a vertical shift: The observer measures the vertical angle to the known point. Knowing the distance from his observation post to the known point and using the mil relation, the observer determines the vertical interval or the amount in meters that the known point is above or below his observation

post. He then computes the vertical interval between his OP and the target. By comparing the known point vertical interval to the target vertical interval, he determines the vertical change (up or down) from his known point to the target.

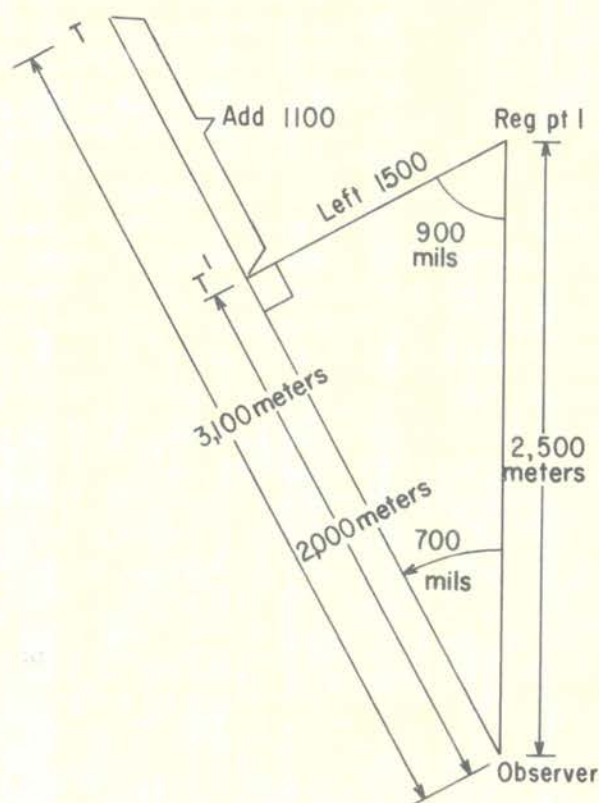
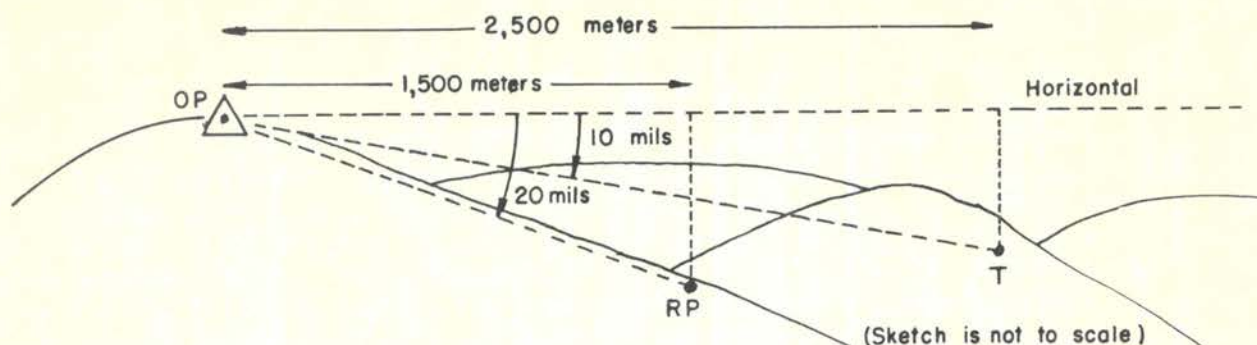


Figure 8-7. Computation of lateral and range shift using sine factor

Example (fig. 8-8): The observer measures a vertical angle of minus 10 mils to a target at a distance of 2,500 meters. The distance and the vertical angle from the OP to the known point are 1,500 meters and minus 20 mils, respectively. In the formula $W = R\eta$, let W represent the vertical interval, η represent the measured angle in mils, and R represent the distance to the target (known point) in thousands of meters. Therefore, $W = -10 \times 2.5 = -25$ meters' vertical interval between the OP and the target. When the same procedure is used, the vertical interval between the OP and the known point is -30 meters ($W = 20 \times 1.5 = -30$). A comparison of results shows the target to be 5 meters about the known point. Thus, the vertical shift would be announced as UP5.



Vertical interval, $OP-RP = -20 \times 1.5 = -30$ meters

Vertical interval, $OP-\text{target} = -10 \times 2.5 = -25$ meters

Vertical shift = UP 5

Figure 8-8. Determination of difference in heights of known point and target

8-7. Target Location by Polar Coordinates

Polar coordinates consist of the direction, distance, and vertical shift from the observer to the target. The observer's location must be plotted on the charts at the FDC if the polar coordinate method is to be used. The principal advantage of the polar coordinates method is the rapidity with which the observer can determine the target location. If the direction is correct and accurate corrections are applied to firing data, the first round(s) fired should fall on or close to the line which passes through the observation post and the target (OT line). Subsequent corrections are then easier to determine. As in the grid coordinate method, the observer measures or computes the direction and estimates the distance to the target. In figure 8-9, the polar coordinates of the target would be reported to the FDC as DIRECTION 1000, DISTANCE 1400. A vertical shift must be made if there is an obvious difference in altitude between the observer's location and the target. The observer, using a BC scope, aiming circle, or M2 compass, measures the vertical angle to the target. This vertical angle is measured from the horizontal plane through the observer's location to the target. Substituting this measured vertical angle and the estimated distance to the target for θ and R , respectively, in the mil relation formula, the observer computes the vertical shift.

Example: The observer measures the vertical angle to the target of +20 mils. The estimated distance to the target from the observation post is 2,000 meters. According to the mil relation,

$$20 = \frac{W}{2.0}, W = 40$$

meters. A vertical shift would then be included as follows: DIRECTION 1000, DISTANCE 1400, UP 40.

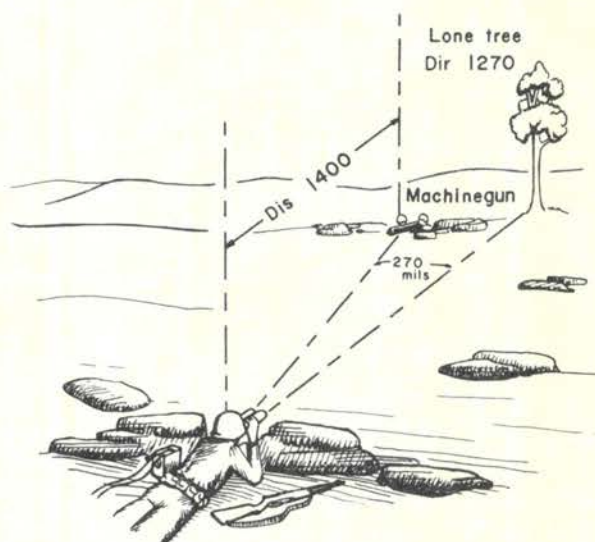


Figure 8-9. Polar plot

8-8. Marking Rounds

Poor visibility, unreliable maps, deceptive terrain, or rapid movement through unfamiliar terrain sometimes makes it difficult, if not impossible, for the observer to orient himself. The observer may call for a marking round(s) to be fired on a registration point, a previously fired target,

or a prominent terrain feature; e.g., MARK REGISTRATION POINT, MARK HILL 437 etc. As a last resort, the observer may call for a round(s) to be fired into the center of the target area; e.g., MARK CENTER OF SECTOR. The observer usually calls for a type of projectile that is easily identifiable, such as white phosphorus or a high airburst. The FDC prepares data which will place the round(s) at the point of impact or burst requested by the observer. If the observer fails to see this round(s), the FDC prepares new data which will move the next round(s) to a dif-

ferent point of impact or will raise the burst higher in the air. This procedure is continued until the observer positively identifies the round(s). He then orders a shift from the point of impact (burst) of the identified round(s) to a target or object which is permanent or semipermanent in nature, such as a tree, crossroads, barn, or ruins of a building. Once this point has been located by adjustment of fire and has been plotted at the FDC, the observer may use it as a known point from which shifts may be made to subsequent targets.

CHAPTER 9

CALLS FOR FIRE

9-1. Elements and Sequence of Calls for Fire

a. When an observer has determined the location of a target on which he wishes to adjust artillery fire, he transmits a call for fire. A call for fire is a concise message prepared by the observer containing all the information needed by the FDC for the determination of data and volume of fire required to achieve the desired result. The call for fire contains six elements arranged in a prescribed sequence.

b. The following is a list of the elements and the sequence in which they are transmitted (para 9-3—9-8):

- (1) Observer identification.
- (2) Warning order.
- (3) Location of target.
- (4) Description of target.
- (5) Method of engagement.
- (6) Method of fire and control.

9-2. Standardization of Terminology

Many military operations involve forces of allied nations. Therefore, the sequence and terminology used in calls for fire has been standardized among Allied Nations so that an observer may call for and adjust the fires of another nation's artillery. For example, *azimuth* is stated as *direction*, and *coordinates* are stated as *grid*. Other examples are evident in the succeeding paragraphs.

9-3. Observer Identification

The element observer identification consists of appropriate call signs or codes necessary to establish contact between the observer and the unit FDC to which he is calling for fire. For example, the observer transmits BIG STALLION 18 (call sign of FDC), THIS IS BIG STALLION 26 (call sign of observer).

9-4. Warning Order

The element warning order is the notice sent by the observer to achieve communication priority and to alert the fire direction center. The warning order is announced as FIRE MISSION. The observer may indicate the size of the fire unit desired in fire for effect following the warning order; for example, FIRE MISSION, BATTALION. The foregoing warning order indicates that the observer desired the battalion to fire for effect.

9-5. Location of Target

a. The location of target contains two or more elements, depending on the manner in which it is reported by the observer. One element which is always required in the call for fire by the ground observer is the reference line. The following are examples of reporting the direction of the spotting line:

(1) Grid azimuth from observer to target; e.g., DIRECTION 4310.

(2) Magnetic azimuth from observer to target; e.g., MAGNETIC DIRECTION 2450.

(3) Gun-target line; e.g., DIRECTION GUN TARGET.

Note. If no direction is ordered by an air observer, the GT line will be used as the a spotting line.

b. When a target is located by grid coordinates, the elements of the target location are transmitted in the following manner:

(1) Grid coordinates; e.g., GRID 675134.

(2) Grid azimuth from observer to target; e.g., DIRECTION 4310.

c. When a target is to be located by a shift from a known point, the elements of the target location are transmitted in the following sequence:

(1) Known point; e.g., FROM TARGET AF2011.

(2) Observer-target azimuth; e.g., DIRECTION 1670.

(3) Lateral shift (if any) e.g.; RIGHT (LEFT) 200.

(4) Range shift (if any); e.g., ADD (DROP) 400.

(5) Vertical shift (if any); e.g., UP (DOWN) 20.

(6) If there is no shift in a particular dimension, that element is omitted; e.g., FROM REGISTRATION POINT 1, DIRECTION 860, RIGHT 400, UP 40 or FROM TARGET AF 2012, DIRECTION 1060, ADD 400, UP 20.

d. The target number and known point are locations which are known to the fire direction center and to the observer. If a known point is to be fired on, the target location would be reported as—

(1) REGISTRATION POINT 2, DIRECTION 4320.

(2) TARGET AF2031, DIRECTION 120.

e. When the location of a target is reported by polar coordinates, the elements of the target location are transmitted in the following sequence:

(1) Observer-target azimuth; e.g., DIRECTION 1620.

(2) Observer-target distance; e.g., DISTANCE 2500.

(3) Vertical shift (if any); e.g., UP 55.

9-6. Description of Target

The element indicating the description of target includes a description of the installation to include degree of protection, personnel, equipment, or activity which is observed. The description should be brief but sufficiently informative to enable the S3 to determine the relative importance of the target and the best manner of attack.

a. The observer should state the approximate number of personnel or units of materiel comprising the target; e.g., 50 INFANTRY, 2 TANKS, AND 1 TRUCK IN OPEN.

b. The observer should give a clear description of the target shape when it is significant. When the target is rectangular in shape, the observer gives the length and width in meters and the azimuth of the long axis to the nearest 50 mils; e.g., 400 by 200, ATTITUDE 2850. When the target is circular the observer gives the radius; e.g., RADIUS 200.

9-7. Method of Engagement

a. *Type of Adjustment.* In adjustment, two types of fire may be employed, area or precision.

(1) If no specific type of adjustment is designated, area fire will be used. In area fire, the adjustment normally is conducted with the two center pieces of the battery.

(2) When precision fire is desired, the observer announces either REGISTRATION or DESTRUCTION, depending on the reason for firing. Only one piece is used during a precision adjustment.

★(3) The term DANGER CLOSE will be included in the method of engagement when the target is within 600 meters of friendly troops.

b. *Type of Trajectory.* A choice of two trajectories normally is available: low-angle or high-angle. When low-angle fire is desired, this element is omitted. If the observer desires high-angle fire, he request HIGH ANGLE. When the observer omits a reference to trajectory but computations in the FDC indicate high-angle fire to be necessary, the S3 will notify the observer that high-angle fire will be used.

c. *Ammunition.* If the observer does not request a projectile or fuze, he will be given shell HE, fuze quick.

(1) The observer may request one type of projectile initially and subsequently request another type of projectile to complete the fire mission. This also applies to fuzes.

(2) When the observer requests smoke, the S3 normally will direct the use of HE initially in the adjustment and smoke for the completion of the adjustment and fire for effect.

(3) When the observer wants a combination of projectiles, and/or fuzes in effect, he must so state in this element of the call for fire; e.g., HE AND WP IN EFFECT and/or VT AND QUICK IN EFFECT.

(4) The observer may also request the volume of fire he deems necessary in fire for effect; e.g., 3 ROUNDS.

d. *Distribution of Fire.*

(1) A parallel sheaf usually is fired on an area target in fire for effect. When another

type of sheaf is desired, the observer must so announce; e.g., CONVERGE or SHEAF 100 METERS.

(2) Distribution of fire on an area target may also be accomplished by spreading the fire of the battalion in direction or in range. The standard spread is 100 meters. One battery fires at the adjusting point, and the other batteries fire the spread: one battery firing 100 meters beyond or right and the other battery firing 100 meters short or left of the adjusting point.

(3) If the observer desires to spread the fires of the battalion, he will request either RANGE SPREAD or LATERAL SPREAD. The fires of the battalion can also be fired as a half-range or a half-lateral spread. In order to determine which spread will be most effective, the observer must keep in mind that all spreads are with relation to the gun-target line, not the observer-target line.

9-8. Method of Fire and Control

a. Method of Fire. In area fire, the adjustment normally is conducted with the two center pieces of the adjusting battery firing simultaneously. If for any reason the observer determines that PLATOON RIGHT (LEFT) will be more adequate, he may request it. The normal interval of time between rounds fired by a platoon or battery right or left is 5 seconds. If the observer wants some other interval, he may so specify.

b. Method of Control. The control element indicates the control which the observer will exercise over the time of delivery of fire and whether an adjustment is to be made or fire is to be delivered without adjustment. Method of control is announced by the observer by use of the terms below.

(1) *At my command.* AT MY COMMAND indicates that the observer desires to control the time of delivery of fire. The observer announces AT MY COMMAND immediately preceding the announcement in (2) or (3) below; e.g., AT MY COMMAND, ADJUST FIRE or AT MY COMMAND, FIRE FOR EFFECT. When the pieces are ready to fire, the FDC personnel announce BATTERY (BATTALION) IS READY to the observer, who an-

nounces FIRE when he desires the pieces to fire. AT MY COMMAND remains in effect until the observer announces CANCEL AT MY COMMAND.

(2) *Adjust fire.* ADJUST FIRE indicates that an adjustment is necessary and that the observer can see and adjust the fire. Unless AT MY COMMAND has been included, ADJUST FIRE also indicates that the firing unit may begin firing when ready.

(3) *Fire for effect.* When the location of a target is sufficiently accurate to eliminate the requirement for an adjustment, the observer announces FIRE FOR EFFECT. Accurate, immediate fire for effect has appreciable surprise value and is preferred whenever possible. Fire for effect without an adjustment is warranted when the target is at a surveyed location, is a target which has been fired upon previously, or is accurately located by an observer. FIRE FOR EFFECT indicates that the observer can see the fires and, unless the observer has requested that the mission be conducted AT MY COMMAND, that the firing unit may begin firing when ready.

(4) *Cannot observe.* CANNOT OBSERVE indicates that the observer is unable to adjust fire; however, he has reason to believe that a target exists at the given location and that it is of sufficient importance to justify firing on it without adjustment.

9-9. Call for Fire

The call for fire is divided into six elements, some of which contain several subelements. When transmitting the call for fire, the observer may announce two or more elements in one transmission commensurate with established procedures and the training and experience of personnel concerned. Examples of the elements and subelements contained in a call for fire are shown in table 9-1. (Basic radiotelephone procedure is prescribed by ACP-125.)

9-10. Correction of Errors

★*a.* Errors may be made by the observer transmitting erroneous data or by the FDC personnel transmitting an incorrect read-back. If an observer realizes that he has made an error in his transmission, he announces

Table 9-1. The Call for Fire

Element	When omitted	Examples				
		1. Registration using surveyed chart.	2. Area mission using polar plot.	3. Destruction mission using shift from a known point.	4. Area mission using pre-arranged data.	5. Area mission firing high-angle fire.
a. Identification of observer.	Never	BIG BOY 18, THIS IS BIG BOY 25.	RED BACK 18, THIS IS RED BACK 26.	WHITE HORSE 18, THIS IS WHITE HORSE 26.	LONG ROPE 18, THIS IS LONG ROPE 25.	DARK NITE 18, THIS IS DARK NITE 26.
b. Warning	Never	FIRE MISSION	FIRE MISSION	FIRE MISSION	FIRE MISSION, BATTALION.	FIRE MISSION.
c. Location of target.	Never	REGISTRATION POINT 2, DIRECTION 4670.	DIRECTION 2720, DISTANCE 3500, UP 30	FROM REGISTRATION POINT 1, DIRECTION 2120, LEFT 400, ADD 600 DOWN 30	TARGET AF2302 DIRECTION 4600.	GRID 712684, DIRECTION 4060.
d. Description of target.	In a registration	Omitted	60 INFANTRY IN OPEN, 150 BY 300, ATTITUDE 800	BUNKER	5 TANKS AND COMPANY OF INFANTRY	MORTAR FIRING.
☆e. Method of engagement.						
(1) Type of adjustment.	Area fire	REGISTRATION	Omitted	DESTRUCTION	Omitted	DANGER CLOSE.
(2) Trajectory	Low-angle fire	Omitted	Omitted	Omitted	Omitted	HIGH ANGLE.
(3) Ammunition						
(a) Type of projectile.	When shell HE is desired.	Omitted	Omitted	Omitted	HE AND WP, 3 ROUNDS.	Omitted
(b) Fuze action	When fuze quick is desired or when HC smoke or illuminating shell is requested.	Omitted	TIME IN EFFECT	Omitted	Omitted	VT IN EFFECT.
(4) Distribution of fire.	When parallel sheaf and no spread are desired.	Omitted	Omitted	Omitted	RANGE SPREAD.	CONVERGE.
f. Method of fire and control.	NEVER	ADJUST FIRE	PLATOON RIGHT, ADJUST FIRE.	ADJUST FIRE	FIRE FOR EFFECT.	ADJUST FIRE.

CORRECTION and transmits the corrected data. If the observer notes that the FDC read-back is incorrect, he announces CORRECTION and transmits the correct data. If two or more elements or subelements of the call for fire were contained in one erroneous transmission, the observer will correct only that element or subelement in error provided the remainder of the transmitted data will not be affected by the correction.

Example: The observer has transmitted FROM REGISTRATION POINT 2, DIRECTION 4680, OVER and immediately realizes that he should have sent DIRECTION 5680. He then announces CORRECTION, DIRECTION 5680, OVER and, after receiving the correct read-back, continues to send the remainder of the call for fire.

b. When an error has been made in a subelement and the correction of that subelement will affect other transmitted data, the incorrect subelement and the affected data will be transmitted in proper sequence following the word CORRECTION.

Example: The observer has transmitted LEFT 200, ADD 400, UP 40, OVER. He then realizes he should have sent DROP 400. To correct this element, he will send CORRECTION, LEFT 200, DROP 400, UP 40, because the LEFT 200 and UP 40 would have been canceled if not included in the corrected transmission.

c. If the observer has transmitted his entire call for fire and then discovers that he has made an error or omitted an element or subelement, the correct version of that element or subelement must be transmitted together with other affected data.

★*Example:* The observer sent BIG STALLION 18, THIS IS BIG STALLION 25, FIRE MISSION OVER—FROM REGISTRATION POINT 2, DIRECTION 5680, OVER—LEFT 200, ADD 400, UP 40, OVER—INFANTRY IN OPEN, TIME IN EFFECT, ADJUST FIRE, OVER. He then realized that VT is a better fuze to use on this target. To correct this error, he must send CORRECTION, VT IN EFFECT, OVER.

CHAPTER 10

ADJUSTMENT PROCEDURE BY GROUND OBSERVER

Section I. GENERAL

10-1. When To Adjust

When the observer cannot locate the target with sufficient accuracy to warrant firing for effect, he will conduct an adjustment. Lack of accuracy in the location may be the result of poor visibility, deceptive terrain, poor maps, or difficulty on the part of the observer in pinpointing the target. If, in his opinion, fire for effect can be delivered on the basis of target location and surprise is desired, he will request FIRE FOR EFFECT in his call for fire. If registration has not been accomplished recently, adjustment may be directed by the S3 regardless of the accuracy of the target location.

10-2. Adjusting Point

The observer must select a point upon which to adjust (adjusting point). In precision fire, the adjusting point is the target. In area fire, the adjusting point should be a well-defined point near the center of the area occupied by the target (fig. 10-1).

10-3. Appearance of Bursts

The observer must be able to identify the type of shell and fuze used from the appearance of the burst(s). Descriptions of types of shells and fuzes with which an observer normally will be concerned are given in *a* through *f* below. These types are applicable to all artillery weapons; however, the size of the bursts will vary in accordance with the caliber of the weapon.

a. Shell HE, Airburst, Fuze Time or Fuze VT. A fuze time or fuze VT airburst is characterized by a flash, a sharp explosion, and a puff of black smoke which becomes elongated along the trajectory. The effect of fragments on the terrain may be seen below the burst if the burst is not too high and soil conditions are favorable.

b. Shell HE, Fuze Delay, Ricochet. A ricochet burst is a low airburst characterized by a flash, a sharp explosion, and a ball of smoke (usually black). Dirt is kicked up by the shell fragments from the side and base spray. Burst appearance

will vary with the nature and condition of the soil and the attitude of the projectile as it bursts. The characteristic flash, black smoke, and sharp explosion of an airburst are indications of an effective ricochet burst.

c. Shell HE, Fuze Quick. A burst resulting from a fuze quick detonation is characterized by black smoke, discolored by dirt, which spreads both upward and laterally. If the impact occurs on a rock or other hard surface, a flash may also appear. Fuze quick fired into a wooded area will sometimes result in airbursts, caused by the projectile striking the trees and detonating before reaching the ground.

d. Shell HE, Fuze Delay, Mine Action. A mine action burst is characterized by the eruption of a vertical column of earth, often with clods of earth. There is very little smoke, and the explosion is muffled.

e. HC and Colored Smoke, Fuze Time. Functioning of an HC or a colored smoke shell with fuze time is characterized by a small burst in the air, produced by the expelling charge, which ejects the smoke canisters from the base of the shell. The canisters fall to the ground emitting their smoke in thin streams. The smoke streams travel an appreciable distance and then billow out.

f. Shell WP, Fuze Quick. A fuze quick WP shell burst is characterized by a fountain of brilliant white smoke and burning phosphorus. Small particles of phosphorus are spread upward and outward as a pillar of smoke forms and rises.

10-4. Fuze Selection for High-Explosive Projectiles

The effect obtained with an HE projectile depends on the fuze action (fig. 10-2). (For a detailed discussion of the effect of HE projectiles, see ch. 27.)

a. Fuze VT. A VT fuze is a radio-activated fuze which detonates the projectile automatically at a predetermined height above the earth's surface. Therefore, a height-of-burst adjustment is not required. During the adjustment, fuze quick

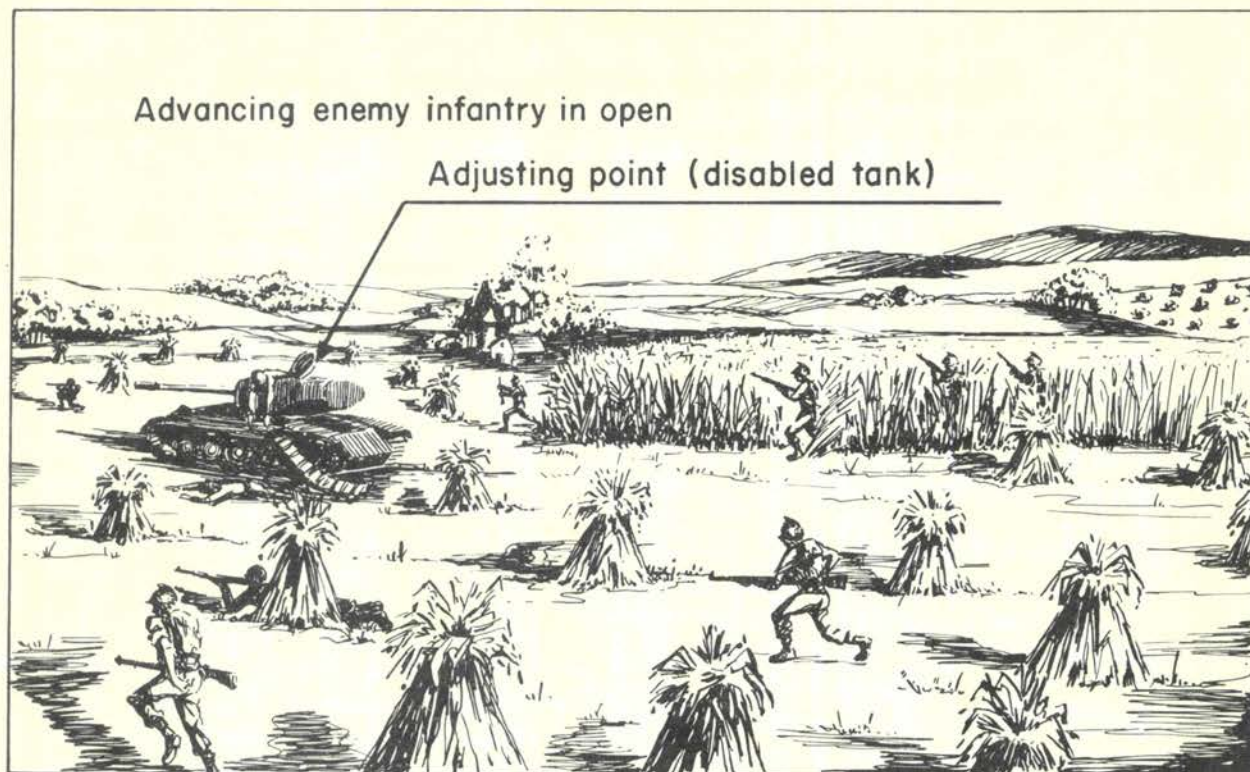


Figure 10-1. Adjusting point in area fire.

normally is employed to obtain greater speed and to facilitate observer spottings. Fuze VT is suitable for use against—

- (1) Personnel in the open.
- (2) Personnel in entrenchments (low-angle fire only).
- (3) Area targets when neutralization is desired.

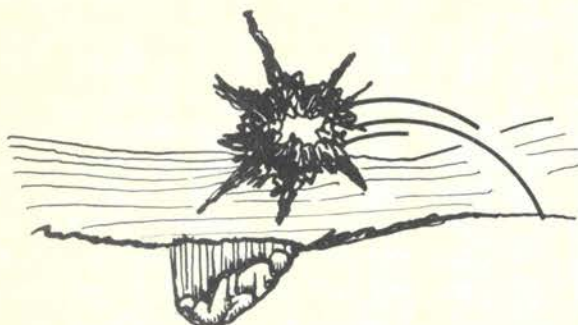
b. Fuze Time. A time fuze detonates the projectile on operation of a preset time mechanism or on impact. The height of burst is controlled by the observer. Since the observer must adjust the height of burst, use of this fuze is more time consuming than fuze VT. However, the fuze time the observer may obtain any height of burst desired. Fuze time is ineffective in high-angle fire, because of the large height of burst probable error involved in the long time of flight. Fuze time is suitable for use against the same types of targets as those against which fuze VT is used, within the limits imposed by the vertical probable error of the fuze.

c. Fuze Delay. When delay action of the fuze is used, the projectile has time after impact and before detonation either to penetrate and produce

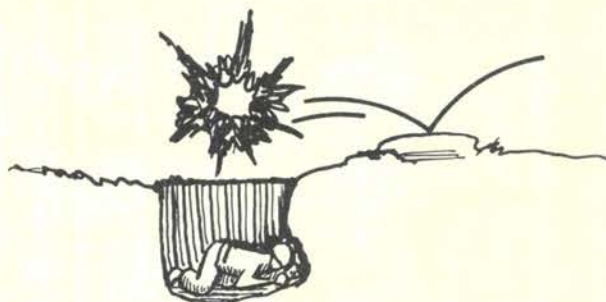
mine action or to ricochet and produce a low air-burst. Fuze delay is used with shell HE for destruction missions which require penetration and for ricochet fire.

- (1) Factors which determine whether a shell will ricochet are angle of impact; shape, weight, and terminal velocity of projectile; length of delay of fuze; and condition of surface of ground, including composition of soil.
- (2) When the angle of impact is small, the projectile tends to ricochet. As the angle of impact increases, the projectile first penetrates and then tends to rise. When the angle of impact is large, the projectile continues downward until it stops or detonates. When penetration occurs, a crater is produced. However, if penetration is very great, the burst may produce a camouflet; that is, a hole underground, the surface of the ground remaining uncratered. Whether a camouflet or a crater is produced depends on the depth

① Fuze time or VT



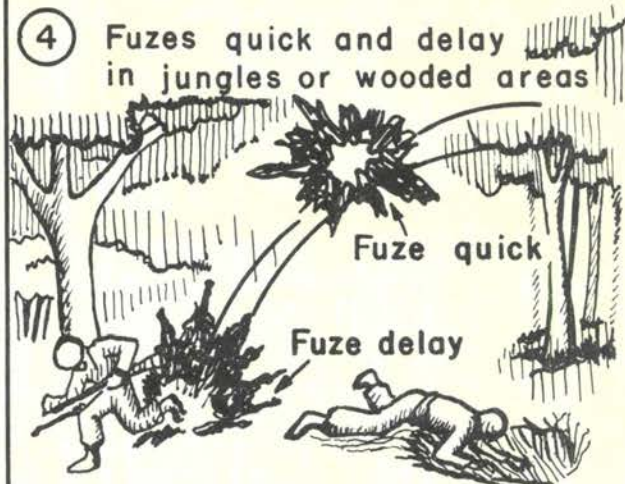
② Fuze delay (ricochet)



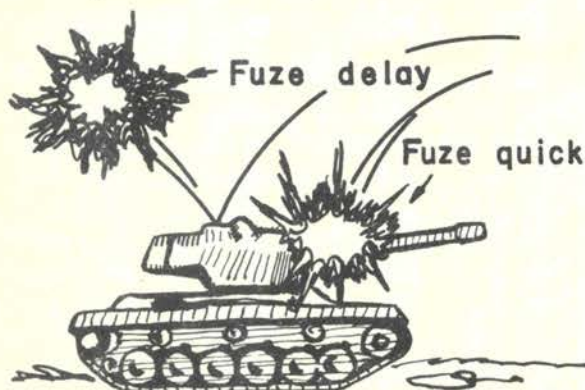
③ Fuze quick



④ Fuzes quick and delay in jungles or wooded areas



⑤ Fuzes quick and delay against armored vehicles



⑥ Fuzes quick and CP against fortified positions

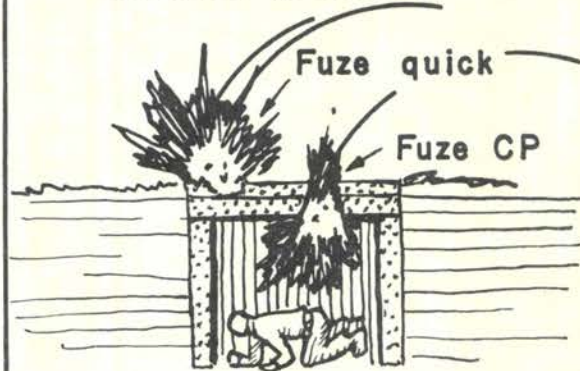


Figure 10-2. Effects of high-explosive bursts.

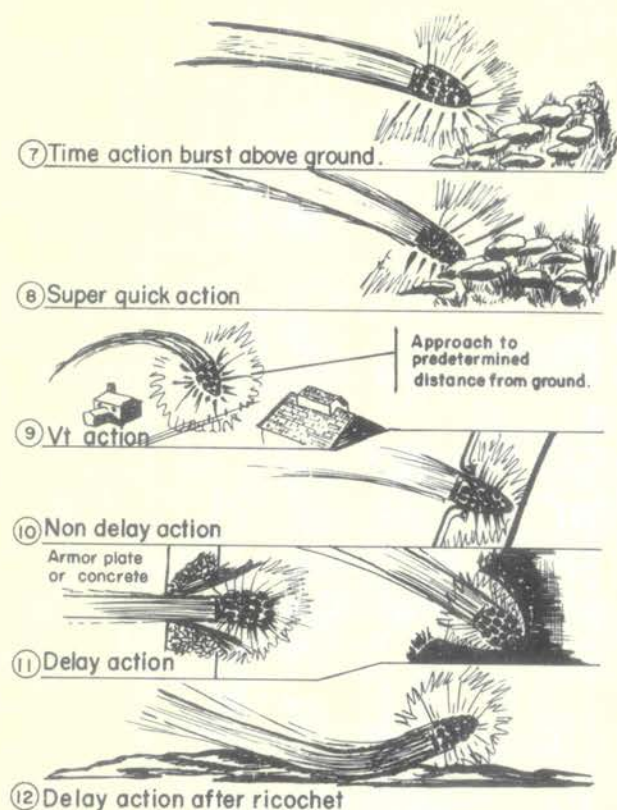


Figure 10-2—Continued

of burst, type of soil, and force of detonation.

- (3) When penetration occurs and the shell is in the earth at the instant of detonation, fragmentation effect above the ground is very small. Penetration into a bunker or dugout will produce casualties by blast effect and fragmentation. Penetration into a structure built of logs, sandbags, or similar materials results in the blowing apart of constituent units. Effectiveness depends on the amount of high-explosive filler. Use of concrete-piercing (CP) fuze increases depth of penetration and the angle at which penetration may be obtained against reinforced concrete or heavy masonry targets.
- (4) Ricochet fire should be used only against personnel in shallow foxholes or shallow trenches. Ricochet fire against these targets is somewhat better than VT or time fuzes because of the lower height of burst and the nose up attitude of the pro-

jectile. The lowered height of burst reduces effect against deeply entrenched targets. Ricochet fire is not used against troops in the open, because, against troops prone in the open, ricochet action would be required from approximately 80 percent of the rounds fired to be as effective as the same number of rounds fired with fuze quick. Factors which determine whether a projectile will ricochet cannot be evaluated for a particular point of impact until the bursts are spotted. Ricochet fire must be observed. Another fuze must be used if ricochet action cannot be expected from at least 50 percent of the rounds fired in fire for effect.

d. Fuze Quick. Quick (superquick) fuze action bursts the projectile immediately on impact. Ease of spotting a fuze quick burst, together with the fact that no height-of-burst adjustment is necessary, makes possible a rapid adjustment. Fuze quick is suitable for use against—

- (1) Personnel in the open (very effective in high-angle fire).
- (2) Personnel in sparsely wooded terrain where tree bursts give the effect of a low airburst.
- (3) Materiel, when penetration is not required.
- (4) Armored vehicles, when used by heavy artillery (concussion).

e. Combined Fuze Action in Fire for Effect. When the target is such that more than one type of fuze action will add to the effectiveness of fire for effect, the observer will include the fuzes desired in the call for fire or subsequent corrections.

10-5. Spottings

Determination by the observer of the location of a burst or group of bursts with respect to the adjusting point as observed along the OT line is called a spotting. Spottings are made for height of burst, range, and deviation. Spottings must be made by the observer at the instant the burst occurs except when delayed to take advantage of drifting smoke or dust.

a. The observer should be required to announce his spottings during his early training. As an observer gains experience, spottings need not be announced.

b. Under certain conditions the observer may be able to make a spotting, even though he is unable to see the burst. For example, if the observer heard the burst and the only possible place where the burst could occur and not be visible to the observer was in a ravine beyond the adjusting point, then the burst could be properly spotted as being beyond the adjusting point.

c. If visibility is temporarily impaired or if the observer is unable to obtain a spotting for a particular round, he reports UNOBSERVED, REPEAT.

★10-6. Corrections

The observer causes the mean point of impact or burst to be placed on, or sufficiently close to, the target by making appropriate corrections during the adjustment. From his spottings, the observer determines deviation and range corrections in meters; he announces these corrections in that sequence as commands to bring the bursts onto the OT line; and to establish the appropriate bracket of the adjusting point along the OT line.

Section II. ADJUSTMENT OF DEVIATION

10-7. Deviation Spottings

a. Deviation is the lateral distance from the burst center to the OT line. A deviation spotting is the angular amount and direction of the deviation. During conduct of fires, the observer measures, in mils, the angular amount from the OT line to the center of each burst or group of bursts (Fig. 10-3).

b. A burst, or the center of a group of bursts, may be on the OT line or it may be right or left of the OT line. Possible deviation spottings are LINE or (so much) RIGHT (LEFT). For example, the observer sees a burst which he measures to be 20 mils to the right of the OT line. His deviation spotting in this instance is 20 RIGHT.

10-8. Deviation Corrections

a. A deviation correction is the distance in meters perpendicular to the OT line required to move a subsequent group of bursts to the OT line. Except when the observer is entering fire for effect, minor deviations (10 to 20 meters) should be ignored in the adjustment of area fire unless such action precludes obtaining range spottings. In the adjustment phase of a precision mission, all deviations, however minor, must be corrected to the OT line.

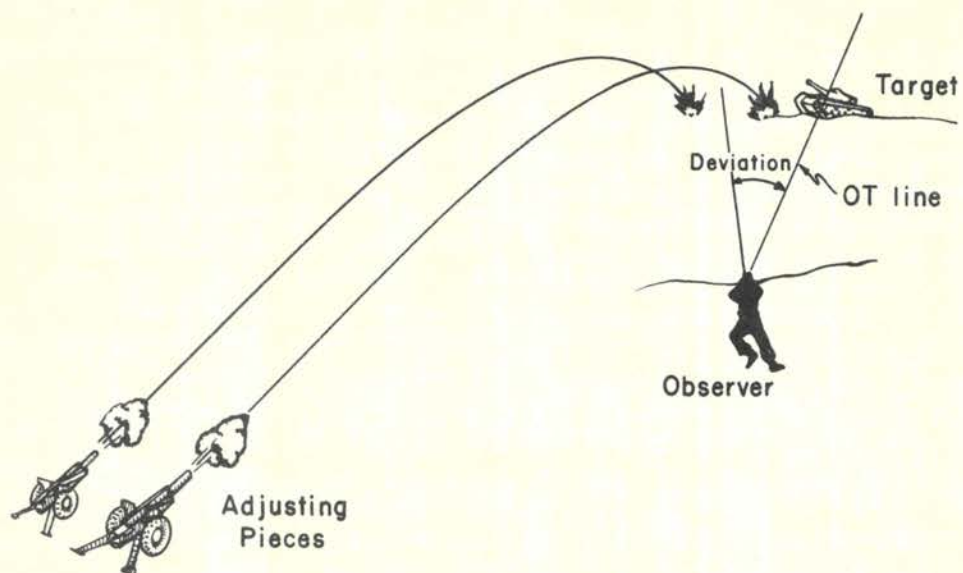
b. Deviation corrections are computed by multiplying the deviation spotting by the OT factor. The OT factor is the OT distance in thousands of meters. If the OT distance is 1,000 meters or greater, the OT factor is expressed to the nearest thousand. If the OT dis-

tance is less than 1,000 meters, the OT factor is expressed to the nearest hundred. The following are examples of computations of deviation corrections:

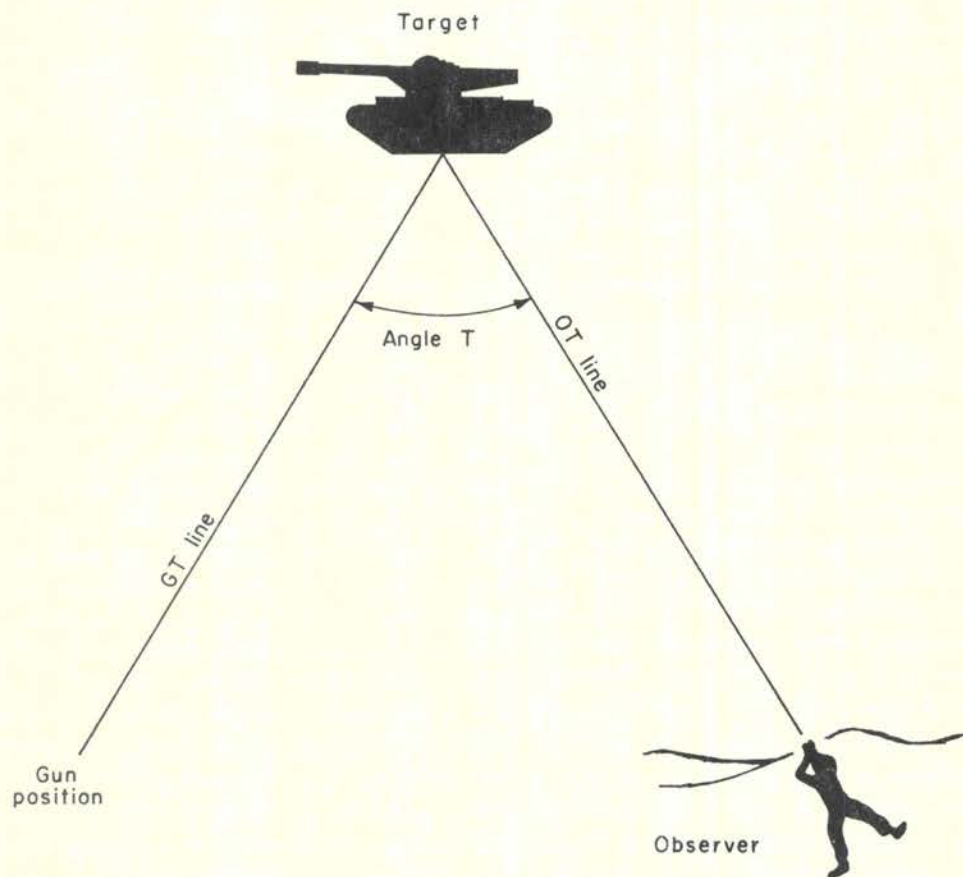
OT distance	OT factor	Spotting	Deviation correction
3600-----	4	40 RIGHT	LEFT 160.
3400-----	3	50 LEFT	RIGHT 150.
800-----	0.8	40 LEFT	RIGHT 30.

c. The deviation correction is expressed to the nearest 10 meters and announced to the FDC as LEFT (RIGHT) (so much). The direction of the correction is always opposite the direction of the spotting.

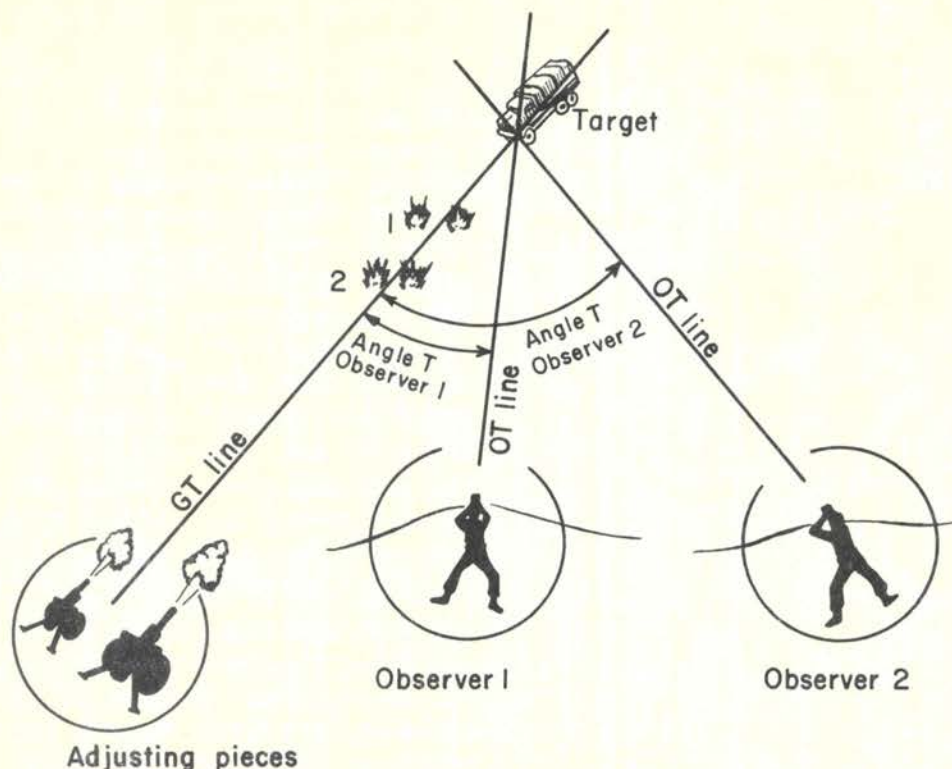
d. When the angle between the OT line and the GT line (angle T) is 500 mils or greater, the fire direction center will notify the observer of this fact after the first SHOT is given (fig. 10-4). When the angle T is large, the observer should consider the range dispersion of the weapon when determining corrections. What the observer sees as deviation may be due, in whole or in part, to range dispersion which cannot be corrected by deviation corrections. In figure 10-5 the two groups of rounds shown were fired at the same deflection and quadrant elevation. The difference in locations of the bursts is due to range dispersion along the GT line. As viewed by observer 1, from whose location the angle T is relatively small, there appears to be little difference in the amount of deviation correction needed to bring the bursts to the OT line. However, as viewed by observer 2, group 2 bursts appear to be



★Figure 10-3. Deviation



★Figure 10-4. Angle T.



★Figure 10-5. The effect of angle T when viewing range dispersion.

twice as far from the OT line as group 1 bursts.

e. The observer must exercise caution in

making deviation corrections in the direction of friendly troops who are close to the target.

Section III. ADJUSTMENT OF RANGE

10-9. General

The normal procedure for the adjustment of range is the establishment of a bracket along the OT line (fig. 10-6). A bracket is established when one group of rounds falls over and one group of rounds falls short of the adjusting point. The observer must establish the bracket early in the adjustment and then successively decrease the size of the bracket until it is appropriate to enter fire for effect.

10-10. Range Spottings

a. Definite range spottings are required to make a proper range adjustment. Any range spotting other than DOUBTFUL or LOST (UNOBSERVED) is definite.

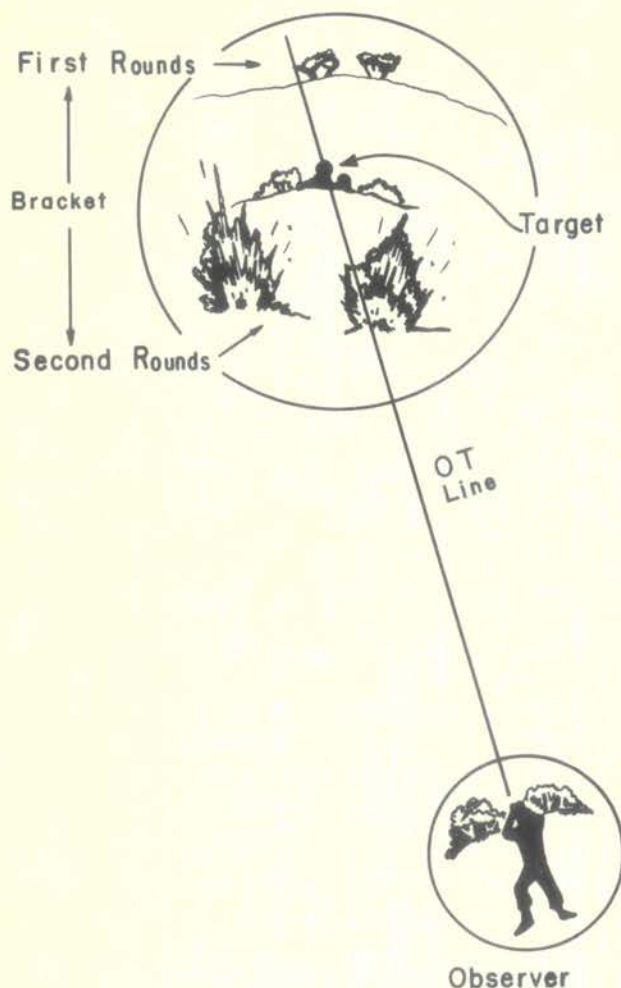
(1) A burst or group of bursts on the OT line normally gives a definite range spotting. Figure 10-7 is a guide showing approximate areas for the various spottings.

(2) Definite range spottings may be made when the burst(s) is not on the OT line by using a knowledge of the terrain, drifting smoke, shadows, and wind. However, even experienced observers must exercise caution and good judgment when making such spottings.

(3) Spottings of airbursts for range are based on the location of the burst fragmentation pattern on the ground.

b. Possible range spottings are as follows:

(1) *Over.* A burst(s) which appears beyond the adjustment point is OVER.



★Figure 10-6. Establishing a bracket for range.

(2) *Short*. A burst(s) which appears between the observer and the adjusting point is **SHORT**.

(3) *Target*. An impact burst which hits the target is spotted **TARGET**. This spotting is used *only in precision fire*.

(4) *Range correct*. A burst or center of a group of bursts which is at the proper range is

RANGE CORRECT. (This spotting is not used in the fire-for-effect phase of a precision mission.)

(5) *Doubtful*. A burst which can be observed but cannot be determined as over, short, target, or range correct is **DOUBTFUL**. A burst which appears range correct in the fire-for-effect phase of a precision mission is spotted **DOUBTFUL**.

(6) *Lost*. A burst is **LOST** when its location cannot be determined. **LOST** rounds must be reported to the FDC and a bold shift in deviation or range should be made.

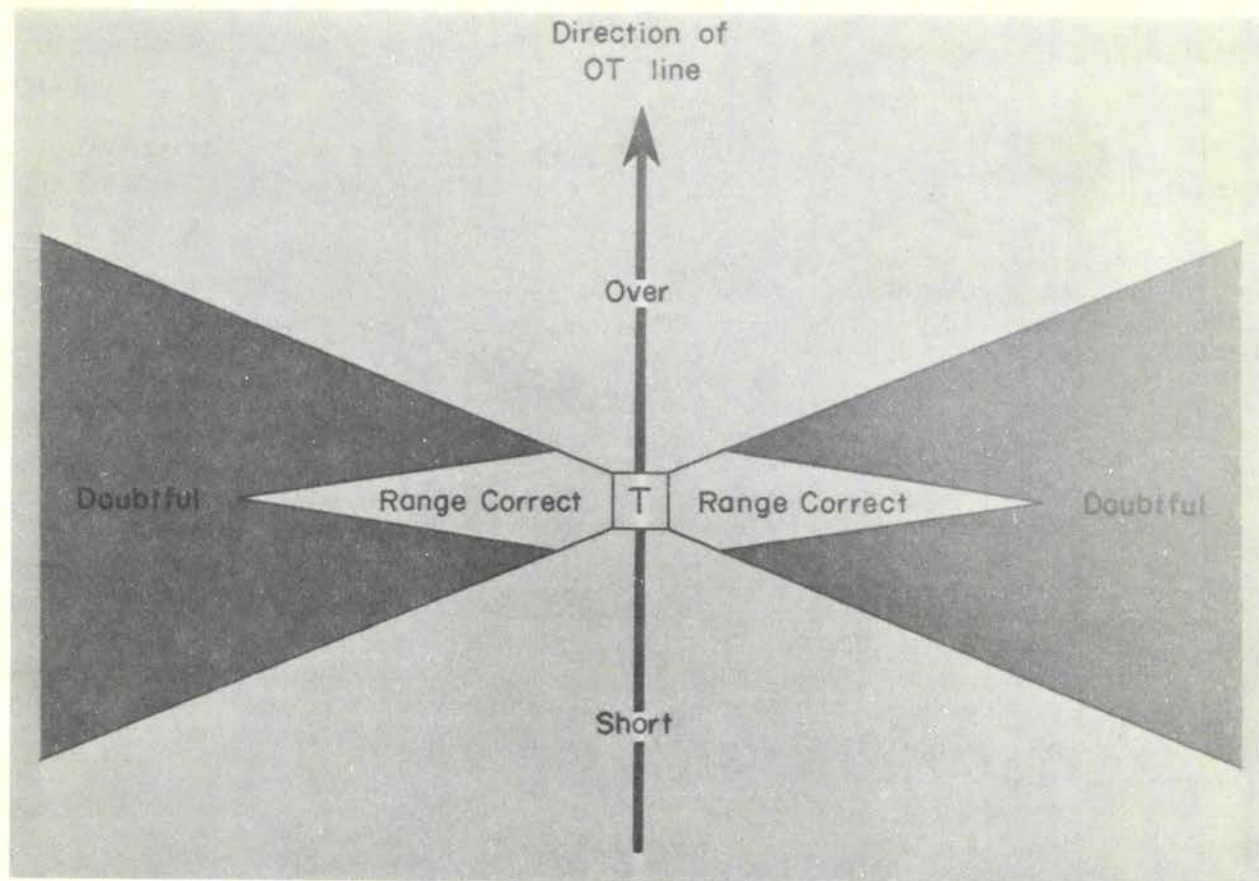
(7) *Lost over (short)*. A burst which is not observed but is known to be definitely beyond or short of the adjusting point is reported as **LOST OVER** or **LOST SHORT**.

10-11. Bracketing

a. When the first definite range spotting is obtained, the observer should make a range correction that can be expected to result in a range spotting in the opposite direction; e.g., if the first definite range spotting is **SHORT**, the observer should add enough to obtain an **OVER** on the next round or group of rounds. As a guide, after the first definite range spotting, a range change of 400 meters is suggested if the initial target location is estimated or a range change of 200 meters is suggested if the initial target location is surveyed.

b. Once a bracket has been established it is successively decreased, normally by splitting, until it is appropriate to enter fire for effect. Fire for effect is normally asked for in area fire when a 100-meter bracket is split or fire on the target is observed.

c. The procedures in *a* and *b* above are not to be considered inflexible. The observer must use his knowledge of the terrain, knowledge gained from previous firing, general experi-



★Figure 10-7. Range spottings.

ence, and good judgment in determining the size of the initial and subsequent range changes. For example, if the observer adds 800 after an initial range spotting of SHORT and the second range spotting is OVER but the bursts are much closer to the adjusting point than the initial rounds, a range change of DROP 200 would be appropriate.

d. When the observer requests an adjustment on a target close to friendly troops, he makes range corrections toward friendly elements in increments which he considers safe.

He does not necessarily attempt to bracket the target with any successive corrections. As his corrections bring the bursts closer to the target, definite range spottings can be made easily. A greater expenditure of ammunition and time may result when small, safe shifts are made rather than the normal bracket but may be necessary to insure safety (fig. 10-9). An adjustment made in this manner is referred to as *creeping*.

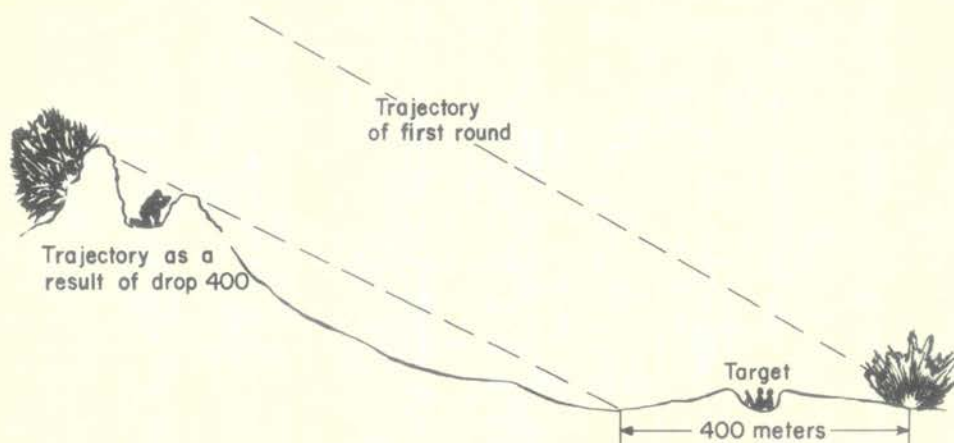
Figure 10-8. Rescinded.

Section IV. ADJUSTMENT OF HEIGHT OF BURST

10-12. General

In firing fuze time in area fire, the observer must adjust the height of burst. The adjust-

ment of deviation and range is conducted with fuze quick and upon splitting the appropriate range bracket, normally 100 meters, or on ob-



★Figure 10-9. Need for creeping when close to friendly troops.

taining a range correct spotting, the adjustment of height of burst is begun and normally further corrections to deviations and range are not required. The observer spots height of burst and determines and announces the correction to the nearest 5 meters as UP (DOWN) (so much) to raise or lower the bursts to the desired height. Computations are made by using the mil relation in the same manner as for deviation shifts. The proper height of burst for fire for effect is normally 20 meters above the target. Any time two bursts are widely separated in height the observer must report this fact to the FDC. When fuze delay is being used for ricochet fire, no correction for height of burst can be made. When VT fuze is used, only malfunctions and graze bursts are reported.

Figure 10-10. Rescinded

★10-13. Height of Burst Spottings

Height of burst spottings for fuze time are as follows:

- a. *Air*. A round or group of rounds bursting in the air is spotted *AIR*.
- b. *Graze*. A round or group of rounds bursting on impact is spotted *GRAZE*.
- c. *Mixed*. A group of rounds resulting in an equal number of air bursts and graze bursts is spotted *MIXED*.
- d. *Mixed Air*. A group of rounds resulting in

both air bursts and graze bursts is spotted *MIXED AIR* when the majority of the bursts are airbursts.

e. *Mixed Graze*. A group of rounds resulting in both air bursts and graze bursts is spotted *MIXED GRAZE* when the majority of the bursts are graze bursts.

★10-14. Height of Burst During Adjustment

a. The adjustment of time fuze is begun at the split of the appropriate range bracket with the objective of obtaining a 20 meter height of burst. Fire for effect is entered only when a correct height of burst (20 meters) is assured.

b. During the adjustment of time fuze there are three possible height of burst spottings—*AIR*, *GRAZE*, or *MIXED*. Rules for height of burst adjustment are as follows:

(1) When the initial rounds are *AIR*, adjust to 20 meter height of burst and fire for effect. However, if very high airbursts are obtained and the observer is not sure that the next correction will produce a 20 meter height of burst, a correction to HOB without entering fire for effect is appropriate (judgment and experience are the governing factors).

(2) When the initial rounds are *GRAZE*, apply UP 40 and continue the adjustment. A 40 meter height of burst correction will be applied until spottings of *AIR* or *MIXED* are ob-

tained and then the rules in (1) above or (3) below apply.

(3) When the initial rounds are MIXED, apply UP 20 and fire for effect.

(4) Widely separated bursts must be reported to the FDC and in most cases a repeat command is given, e.g., "REPEAT, 100 METER HEIGHT OF BURST SPREAD; 60 METER MEAN HEIGHT OF BURST."

c. The height of burst is determined by measuring the vertical deviation in mils between the target and the burst or the center of the group of bursts and then multiplying the vertical deviation by the OT factor. The height of burst thus determined is compared with the desired height of burst in order to compute the correction.

Example: The OT factor is 3. The observer measures the vertical deviation from the target to the burst as plus 20 mils. The height of burst is then 60 meters above the target ($W = R \times \text{OT} = 3 \times 20$). The correction is DOWN 40, FFE (the desired height of burst is 20 meters and the 60

meters is 40 meters above the desired height of burst).

10-15. Fuze Delay

When fuze delay is employed for ricochet action, no adjustment of height of burst is possible. The observer notes the number of airbursts and graze bursts in each group. If the two groups which establish the bracket to be split to enter fire for effect or a group which itself bracketed the adjusting point contained 50 percent or more airburst, fire for effect is begun with fuze delay. If more than 50 percent of the bursts were graze, the observer requests either VT or QUICK, whichever is more appropriate.

10-16. Fuze VT

No adjustment of height or burst is possible with fuze VT. The height of burst is influenced by the angle of fall of the projectile; the greater the angle of fall, the lower the height of burst.

Section V. SUBSEQUENT CORRECTIONS

10-17. General

a. After the initial burst (s) appears, the observer transmits subsequent corrections until the mission is completed. These corrections include appropriate changes in elements previously transmitted and the necessary corrections for deviation, range, and height of burst. Elements that may require correcting and the order in which corrections are announced are as follows:

- (1) Observer-target direction.
- (2) Trajectory.
- (3) Method of fire.
- (4) Distribution.
- (5) Projectile.
- (6) Fuze.
- (7) Deviation.
- (8) Range.
- (9) Height of burst.
- (10) Control.

b. Any element for which a change or correction is not desired is omitted.

10-18. Change in Observer-Target Direction

A change in observer-target direction is given when it deviates from the announced direction by more than 100 mils. For example, an observer began an adjustment on several self-propelled guns, using a tree at direction 5620 as the adjusting point. During the adjustment the self-propelled guns moved to a new position an appreciable distance from the adjusting point. The observer selects a new adjusting point in the vicinity of the target and measures direction 5840 to that point. The first element of his next correction is DIRECTION 5840.

10-19. Change in Trajectory

The observer requests a change in the trajectory during a low-angle adjustment when it becomes apparent that high-angle fire will be necessary or during a high-angle adjustment when it becomes apparent that high-angle fire is no longer required. For example, an observer is making an

adjustment on some moving armored personnel carriers. During the adjustment the target moves into a deep gully for cover. Knowing from previous firing in the area that high-angle fire will be necessary to bring effective fire into the gully, the observer requests HIGH ANGLE. Conversely, an observer is making a high-angle adjustment on a column of vehicles halted along a street in a town constructed of tall buildings. During the adjustment the vehicles move out toward the edge of town. As soon as he notices the vehicles emerging from the town, the observer should request CANCEL HIGH ANGLE to expedite the firing.

10-20. Change in Method of Fire

The observer must announce any change he desires in the method of fire. For example, in order to change from pieces firing simultaneously to pieces firing in order from left to right the observer requests PLATOON LEFT. This change may be requested to take advantage of the wind when smoke shells are being fired or to clarify spottings when one burst is obscuring another. PLATOON LEFT is cancelled by saying CANCEL PLATOON LEFT.

10-21. Change in Distribution

If the observer desires a sheaf other than parallel, he must specify the type desired; e.g., CONVERGE, OPEN, SHEAF 100 METERS. If the observer wishes to change to a parallel sheaf during adjustment or fire for effect, he requests CANCEL (CONVERGE, OPEN, SHEAF 100 METERS).

10-22. Change in Projectile

When the observer desires to change the type of projectile, he announces the desired change; e.g., WP, SMOKE, etc.

10-23. Change in Fuze

When the observer desires to change the fuze or fuze action, he announces the desired change; e.g., VT, DELAY, etc.

10-24. Correction for Deviation

The observer transmits deviation corrections to the nearest 10 meters as RIGHT (LEFT) (so much).

10-25. Correction for Range

If there is no range correction, the range element is omitted; e.g., RIGHT 200, OVER.

a. *ADD*. The term "ADD" is used by the observer to move subsequent burst (s) away from the observer along or parallel to the OT line. If the burst (s) falls short of the target, the observer commands ADD (so much).

b. *DROP*. The term "DROP" is used by the observer to move subsequent burst (s) toward the observer along or parallel to the OT line. If the burst (s) appears beyond the target, the observer commands DROP (so much).

10-26. Correction for Height of Burst

The observer transmits height-of-burst corrections to the nearest 5 meters as UP (DOWN) (so much).

10-27. Change in Control

When the observer desires to change the method of control (other than AT MY COMMAND, paragraph 9-8b(1)), he announces the new method of control; e.g., FIRE FOR EFFECT.

10-28. Repeating Previously Fired Data

*a. The term "repeat" is used to indicate that the observer desires a subsequent round or group of rounds fired with no corrections to deviation, range or height of burst. For example, if several rounds burst in the area of observation simultaneously and the observer could not determine which rounds to observe, he would request REPEAT or WP REPEAT.

b. The term "REPEAT" is also used to indicate that the observer wants fire for effect repeated with or without changes or corrections to any of the elements; e.g., ADD 50, REPEAT.

10-29. Correction of Errors.

If the observer discovers an error or omission in the transmission or read-back of a subsequent correction, he corrects the error as outlined in paragraph 9-10.

10-30. Additional Information

If the observer desires to transmit information necessary to the conduct of a mission and there

is no specific format prescribed, he should transmit the information in clear, concise language in a sequence least likely to cause confusion and most likely to expedite the mission.

10-31. Calls for Fire From Higher Headquarters

Calls for fire from higher headquarters and calls for fire from the observer are similar in format. Higher headquarters' call for fire will specify in the warning order the fire unit to fire for effect, whereas the observer's call for fire can only request the fire unit. An example of a call for fire from higher headquarters is as follows:

Warning order ..	FIRE MISSION, BATTALION.
Target location ..	TARGET AF1201.
Description of target.	INFANTRY BATTALION ASSEMBLY AREA.
★Method of engagement.	VT 3 ROUNDS.
Control	TIME ON TARGET WILL BE 10 MINUTES FROM— NOW.

The time on target may be set by giving the time of day that fire is to be delivered. For example, the order may state TIME ON TARGET IS 0915, TIME IS 0903—NOW.

Note. Projectile and fuze if other than HE quick will be specified.

CHAPTER 11

ADJUSTMENT OF FIRE BY THE AIR OBSERVER

Section I. INTRODUCTION

11-1. General

Observation and adjustment of artillery fires may be accomplished from the air using organic Army aircraft or Air Force high-performance aircraft. An air observer normally is employed, since it is difficult for a pilot to navigate and observe at the same time. However, the pilot should be well trained in the adjustment of fire, since such knowledge is invaluable in training a new air observer and increases the flexibility in obtaining prompt and accurate fire if an observer is not available.

11-2. Observation From Army Aircraft

Observation from organic Army aircraft normally is limited to altitudes and locations which allow the aircraft to avoid enemy ground fire and enemy fighter aircraft.

11-3. Observation From High-Performance Aircraft

Use of high-performance aircraft provides observation deep into enemy territory beyond the limits of organic Army aircraft. The pilot and observer can fly over enemy territory to sufficient depth to observe and adjust long-range artillery fire. Usually two aircraft are used on a mission—one to adjust the fire and the other to observe for hostile aircraft. Danger from both hostile air defense artillery and hostile planes usually increases as the duration of the flight and the depth into hostile territory increases. For this reason the air observer must minimize the time required for an adjustment.

Section II. PREFLIGHT PREPARATIONS

11-4. General

The air observer and pilot should be given a preflight briefing by the intelligence (S2) and operations (S3) officers.

11-5. Preflight Briefing

a. All pilots and observers flying a mission should be briefed on all points pertinent to the mission, including—

- (1) Locations of battery position areas, registration points, targets, known points, reference lines to be used in making corrections (if GT line is not used), suspected targets, and areas to be searched.
- (2) Tactical situation, to include locations of

friendly troops and no-fire lines and zones of action of supported troops.

- (3) Surveillance required, time of mission, type of adjustment to be made, maps and photographs to be used, known enemy air defense, flight instructions, and security restrictions.
- (4) Communication details, to include locations of ground radios and panel stations, channels to be used, call signs, check-in time(s), and prearranged signals.

b. All important enemy locations, lines, and areas discussed in the briefing are recorded on the appropriate map. Photographs, oblique or vertical, are gridded when possible and direction and locations of critical points, lines, and areas are marked on the photographs.

Section III. DETERMINATION OF INITIAL DATA

11-6. General

The air observer must transmit a call for fire in the same sequence as the ground observer. Most target locations are given as military grid refer-

ences; other target locations are given in terms of a shift from a known point and a reference line. Since the plane is constantly moving, the observer-target line method of adjustment is not applicable.

Therefore, spottings are based on a given reference line instead of an observer-target line.

11-7. Determination of a Spotting Line

The air observer makes spottings and corrections with respect to a spotting line. The spotting line and its direction must be known by the FDC personnel of the unit for which the observer is adjusting fires. If possible, the spotting line is established prior to flight. There are three spotting lines which the observer may select for use in making his adjustment—the gun-target (GT) line, a line of known direction, or a convenient spotting line which the observer selects when in flight and describes in sufficient detail so that the FDC personnel can determine its direction. Since the observer is moving continuously, his spotting line on the ground must be easily identified and distinctly visible. In addition, the observer should select a prominent terrain feature or object near the target to facilitate target identification at all times.

a. Gun-Target Line. The observer may select the GT line as his spotting line. If the observer knows the locations of the weapons, visualization of the GT line is facilitated. If he does not know the location of the weapons, the observer requests RANGING ROUNDS in the distribution of fire. These two rounds fired at the same deflection but 400 meters apart in range will enable the observer to visualize the GT line. If fire direction personnel of the adjusting battery are conducting the mission and the observer's aircraft has a homing capability, the GT line can be easily determined prior to firing. The aircraft can be maneuvered over the target area. At the observer's request, the adjusting battery's radio operator keys the radio for 20-30 seconds. The aviator then turns the aircraft in the appropriate direction (left or right) until the on-course signal is received. Once the observer determines the direction of the GT line, he should select terrain features, such as a road; stream, or ridgeline which will assist him in remembering the GT direction. If no spotting line is stated by the observer, the GT line will be used in the FDC as the spotting line.

b. A LINE of Known Direction. The observer may select a line formed by a road, a railroad, a canal, or any series of objects. Prior to flight the observer selects the line and determines its direction; he informs the FDC of this line and direction

and that he will base his spottings and corrections on this line.

c. A Convenient Spotting Line. While in flight, the air observer may select a spotting line which is convenient and easily identifiable. To use this line, the observer must describe it in detail to the FDC personnel so that its direction may be determined. The FDC personnel confirm the location and direction of the line and then notify the observer to commence using it as his spotting line.

11-8. Location of Targets

When a target is observed, its location can be determined and indicated by grid coordinates, by a shift from a known point (marking round) and a spotting line, by a prearranged code, or by cardinal direction.

a. Grid Coordinates. The observer locates the target on his map and transmits the grid coordinates of the location.

b. Shift from a Known Point (Marking Round) and a Spotting Line. The observer may indicate the location of a target by announcing a shift from a known point and a spotting line. The point must be plotted on the firing chart and must be identifiable on the ground by the observer. This point may be a registration point or any point previously located by survey or by firing. The observer announces the shift from the known point to the target in meters; e.g., FROM REGISTRATION POINT 1, RIGHT 400, ADD 800. If any spotting line other than the GT line is used, it must be identified; e.g., FROM TARGET AF2406, SPOTTING LINE NORTH-SOUTH HIGHWAY, RIGHT 400, ADD 800. Subsequent corrections are made in the normal manner. When no maps are available and there has been no previous firing in an area, the air observer may request MARK CENTER OF SECTOR, and then shift from the marking rounds.

c. Prearranged Code. When the location of a target has been established by the FDC personnel and the observer prior to a flight, a code name or target number may be given to it. In this case, the observer need only transmit the preassigned code name or target number to obtain fire on the target.

d. Cardinal Direction. Cardinal points of the compass may be used for locating targets from a reference point; for example, FROM REGISTRATION POINT 1, EAST 400, NORTH 800.

Another example is FROM REGISTRATION POINT 1, CARDINAL NORTH, RIGHT 400, ADD 800.

11-9. Determination of Distance

The observer can determine distance on the

ground by requesting RANGING ROUNDS. The 400-meter range spread obtained from ranging rounds will not only allow accurate visualization of the GT line (para 11-7a), but it will establish a "yardstick" for estimating subsequent range and deviation corrections.

Section IV. ADJUSTMENT PROCEDURES

11-10. General

Adjustment procedures for the air observer are the same as those for the ground observer *except* as noted in paragraph 11-11.

a. Considerations for the selection of an adjustment point are the same for both air and ground observers.

b. The air observer can adjust artillery fire at night by using standard procedures. However, artificial illumination may be necessary to make the target area discernible. The illumination may be accomplished by searchlight, illuminating shells, or parachute flares. When parachute flares are used, it is desirable that the flares be released from an aircraft other than the observer's aircraft so that the observer will not be looking into the target area directly past a burning flare. Night adjustment missions should be planned during daylight hours. Plans should include a daylight flight over the proposed area of operation for the selection of checkpoints and for general terrain orientation. The aerial observer must consider the different shapes and shadows which will be formed in the target area as a result of the illumination. Orientation may also be a problem, especially on very dark nights. However, effective fire can be placed on the target by a well-trained observer.

c. The air observer may use AT MY COMMAND during the adjustment so that the aircraft can be positioned for proper observation of each group of rounds. The time of flight is sent to the observer immediately following the message to the

observer to facilitate aircraft orientation. A new time of flight will be announced when it changes more than 5 seconds from that originally announced. A 5-second splash warning is transmitted from the FDC to the observer for each group of rounds.

11-11. Adjustments

a. *Adjustment of Deviation.* The air observer determines deviation in meters, with respect to the GT line or other spotting line, and announces corrections in meters. In some instances, it may be faster and more accurate to bracket the GT line for deviation than to attempt precise deviation corrections to the GT line.

b. *Adjustment of Range.* The air observer spots bursts for range with respect to the chosen spotting line and the target. Using the bracket method of adjustment, he announces range corrections in meters.

c. *Adjustment of Height of Burst.* The air observer cannot readily determine differences in height of burst; consequently, he seldom will be requested to adjust height of burst. He may be required to observe time registrations in which only spottings of AIR or GRAZE are transmitted.

11-12. Fire for Effect

The air observer calls for and announces spottings during fire for effect in the manner described for a ground observer (para 12-6).

CHAPTER 12

FIRE FOR EFFECT

Section I. PRECISION FIRE

12-1. General

The adjustment in precision fire is conducted with a single piece. (See ch 19 for FDC procedures.)

a. The observer requests fire for effect upon splitting the appropriate range bracket, obtaining a range correct, or obtaining a target hit. The appropriate range bracket to be split upon entering fire for effect is usually 100 meters. However, when the range probable error of the weapon is 38 meters or larger, the FDC will instruct the observer to enter fire for effect when a 200-meter bracket is split.

b. Fire for effect consists of a number of rounds fired singly or in groups of two or three by the adjusting piece. The FDC informs the observer of the number of rounds that are to be fired in the initial group and in subsequent groups if a change is to be made in the number of rounds to be fired. The observer normally does not send corrections during fire for effect. In a precision mission, the observer only announces spottings of bursts as they occur.

c. The observer should report to the FDC the magnitude of the deviation and range error for a particular burst when, in the observer's judgment, the burst is the result of an error and information with respect to the location of the burst will assist the fire direction center. For example, a round in fire for effect is spotted doubtful for range and 100 meters left of the registration point. The observer would transmit a spotting of DOUBTFUL, 100 METERS LEFT. Since spottings normally are made in mils, the word "meters" is used to prevent any misunderstanding. The error is reported in meters because the OT distance may not be known at the fire direction center.

12-2. Registration with Fuze Quick

a. During fire for effect in a registration with fuze quick, the observer announces the range and deviation spotting of each burst. He announces spottings for range as OVER, SHORT, or

DOUBTFUL and for deviations as RIGHT, LEFT, or LINE. The magnitude of the deviation is not announced unless a round appears to be in error. A target hit is spotted as TARGET. These spottings are announced in the order of range and then deviation.

b. Fire for effect is continued until the FDC notifies the observer that the registration is complete.

12-3. Registration with Time Fuze

a. After a registration has been conducted with fuze quick, a time registration may be initiated from the fire direction center. The FDC notifies the observer to OBSERVE TIME REGISTRATION.

b. The observer normally does not send corrections in a time registration but only announces his spotting of each burst as AIR or GRAZE. However, if the height of burst of any round of a time registration is in excess of 50 meters, it is reported; e.g., AIR, 75 METERS. If any round, in the judgment of the observer, is obviously in error for range or deflection, the amount of the error must be determined and reported. For example, a round in fire for effect is spotted to be graze, on line with the target, but estimated to be 100 meters short of the target. The observer transmits GRAZE, 100 METERS SHORT, LINE. Rounds are fired singly until both an airburst and a graze burst have been obtained. The observer continues to report each round as AIR or GRAZE. He must record the height of burst of each round but does not report this information unless it is requested by the fire direction center. The time registration is continued until terminated by the fire direction center.

c. For examples of registrations, see paragraphs 14-2 and 14-3.

12-4. Destruction Mission

a. In a destruction mission, the FDC will direct the use of fuze quick in the initial rounds of fire for effect as well as in the adjustment. This proce-

dures facilitates valid spottings by the observer and expedites determination of an adjusted deflection and quadrant elevation at the fire direction center. Subsequently, the S3 directs the use of the fuze that will be most effective against the target; e.g., fuze delay, fuze concrete-piercing, etc. If this subsequent fuze is not effective, the observer must

request a change to a fuze which, in his opinion, will be more effective.

b. During fire for effect, the observer announces spottings just as he does in a registration with fuze quick.

c. Fire for effect is continued until the observer notifies the FDC that the target has been destroyed.

Section II. AREA FIRE

12-5. General

a. In area fire, the observer normally requests fire for effect at the conclusion of an adjustment. However, he may fire for effect when his target location is accurate enough to preclude the need for adjustment.

b. The type and volume of fire delivered in fire for effect are determined by the S3. His decision is based on the observer's request, description of the target, effect sought, and status of ammunition supply and on other considerations (ch. 27). If fire for effect is ineffective or insufficient, necessary corrections are made and additional fire for effect is requested.

c. Upon completion of fire for effect, the observer sends END OF MISSION and reports the effect observed.

12-6. Fire for Effect After Adjustment

a. *Deviation.* The adjustment of deviation is complete when the mean point of impact or burst is on the OT line. Since, during the adjustment, the observer sends successive deviation corrections to place the bursts on the OT line, it should not be necessary to make a large shift upon entering fire for effect.

b. *Range.* The adjustment of range is complete when the observer has obtained bursts at the same range as the adjusting point (range correct) or when he has split the appropriate range bracket. When the target is fixed, of little depth, and clearly visible or when the fires of more than one battery are massed on the target, it is appropriate to split a 100-meter range bracket. When the target is moving, has substantial depth, or is poorly defined, it may be appropriate to enter fire for effect on splitting a 200-meter range bracket. When the range probable error is 38 meters or larger, the FDC will notify the observer to enter fire for effect on splitting a 200-meter range bracket.

c. *Height of Burst.* When time fuze is being used, fire for effect is not called for until the height of burst is correct or until a correction can be expected to result in the correct height of burst (para 10-14). When fuze delay is being used for ricochet fire, its use is continued on entering fire for effect only if 50 percent or more of the bursts which established the final range bracket were airbursts.

12-7. Distribution

a. Normally, the S3 determines the proper distribution of fire for a target. His decision is based on the observer's call for fire and other available information. Unless the S3 directs, because of the nature and the size of the target, the use of a sheaf other than that normally fired, artillery fires are delivered at center range in a parallel sheaf. The S3 may also direct a battery or batteries to fire through different elevations for greater range coverage.

b. When appropriate, the observer may call for a particular sheaf. This should be announced in the call for fire when possible. It may be announced later if it becomes apparent that the sheaf being fired does not provide satisfactory distribution. In making such a request, the observer announces the type of sheaf desired; e.g., OPEN or SHEAF, 50 METERS.

c. When the number of pieces allocated to the mission is not adequate to cover the target with an open sheaf, the observer may make successive shifts in fire for effect to insure coverage of the target.

12-8. Surveillance of Fire for Effect

The observer carefully observes the results of the fire for effect and then takes whatever action is necessary to complete the mission.

a. If the fire has been effective and sufficient, the observer announces END OF MISSION and re-

ports the effect observed; for example, 20 CASUALTIES, INFANTRY DISPERSED. If he desires to make a correction to improve the accuracy of the replot of the target but not to repeat fire, he announces the correction; e.g., LEFT 20, and follows it immediately by END OF MISSION.

b. If the fire has been insufficient but accurate, including an effective height of burst, the observer may request REPEAT to obtain additional fire.

c. If any element of the fire for effect (deviation, range or height of burst) was sufficiently in error so that the effect sought was not obtained, the observer should correct the element(s) in error

and continue to fire for effect; for example, ADD 50, DOWN 10, REPEAT.

d. If ricochet action with fuze delay was indicated and sought, but during fire for effect fewer than 50 percent of the bursts were airbursts, the observer requests a change to fuze VT and calls for additional fire, if needed; for example, VT, REPEAT.

e. If the observer desires that the target be replotted for future use, he announces appropriate corrections; e.g., RECORD AS TARGET, END OF MISSION, and reports the effect observed.

f. For an example of an area mission, see paragraph 14-4.

CHAPTER 13

ADJUSTMENT PROCEDURE FOR SPECIAL SITUATIONS

Section I. CONDUCT OF FIRE WITH CHEMICAL PROJECTILES

13-1. General

Chemical projectiles include smoke (base-ejection smoke and white phosphorus) and toxic chemical (irritant or lethal agents). For detailed uses of toxic chemical projectiles, see FM 3-5 and FM 3-10.

13-2. Base-Ejection Smoke Projectiles

a. General. Smoke projectiles are used as a screen against enemy observation, as an aid in the adjustment of fire (fire to help the observer in locating rounds), as a prearranged signal, and as a marking round for air observation or an airstrike. Requests for smoke curtains may sometimes be denied, since such missions must be coordinated with higher authority to avoid interference with other operations. (See ch. 24 for FDC procedures.)

b. Colored Smoke. Base-ejection colored smoke projectile (white, green, red, and yellow) is used as an aid to the observer in locating his rounds, as a prearranged signal, and as marking rounds fired at a predesignated point to guide an airstrike to a target. See paragraph 13-3 for adjustment procedures.

c. The Effect of Weather on Smoke. The effects of weather conditions on the performance of smoke for both BE and WP smoke are similar in nature, though different in magnitude. The principal difference between BE and WP smoke is in the rate of fire needed to insure continuous screening.

- (1) *Wind strength.* A strong wind disperses the smoke quickly; however, if there is little or no wind, the smoke may thin out by natural dispersion before it has been effectively carried downwind. The best wind is a steady one of about 4 to 10 knots.
- (2) *Humidity of the atmosphere.* Smoke disperses more rapidly in a dry atmosphere than in a moist atmosphere. Therefore, low humidity requires a high rate of fire to maintain an effective smokescreen.

(3) *Turbulence of the atmosphere.* Turbulence is caused by hot air rising from the ground and disturbing the atmosphere. Turbulence may cause the smoke to drift irregularly, may cause windows to develop, and when severe, may cause pillaring.

- (a) High turbulence—occurs on calm, sunny days.
- (b) Moderate turbulence—occurs when it is overcast (cloudy). When the wind exceeds 10 knots, turbulence is always moderate regardless of existing weather conditions.
- (c) Low turbulence—occurs on clear nights and for about 1 hour before sunset or after sunset; when the sky is clear and the wind is light.

d. Selection of Adjusting Point(s).

- (1) Careful selection of the adjusting point(s) is necessary if full advantage is to be taken of the smokescreen. The factors which determine the selection of the adjusting point(s) are—
 - (a) The area to be blinded; i.e., the ground containing the enemy from which our own activities are to be hidden.
 - (b) The area to be screened; i.e., the ground over which our own troops must pass.
 - (c) The direction of the wind. (The strength of the wind affects only the rate of fire.)
- (2) The areas to be blinded and screened will be pointed out on the ground or map by the supported unit commander or the artillery commander ordering the smoke-screen. The direction of the wind is determined by the observer. The principle of selecting the adjusting point(s) is illustrated in figure 13-1.
 - (a) In figure 13-1, it is clear that the smoke must be across the area DEFG and be effective between X and Y.

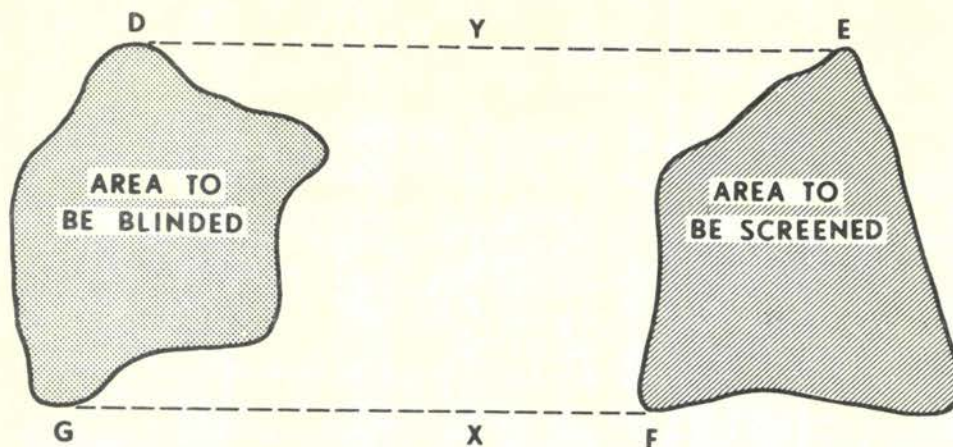


Figure 13-1. Selection of adjusting point(s)

Normally, line XY should be placed close to the area to be blinded so that the smoke causes the most inconvenience to the enemy and very little inconvenience to our own troops. However, there are occasions when the smokescreen should be close to the area to be screened; e.g., when the area to be screened is much smaller than the area to be blinded or when the ground makes it difficult to place the smoke near the enemy without being too far downhill.

- (b) Figure 13-1 shows how the number and selection of adjusting points, in order to produce an effective smoke-screen along the line XY, depends on the direction of the wind. Winds are classified as follows:

1. *Flank wind.* A wind within 500 mils of the line XY is considered as a flank wind. The adjusting point(s) must be upwind of X.
2. *Oblique wind.* An oblique wind is a wind blowing partly towards the enemy or partly away from the enemy. A wind between 500 and 1,300 mils of line XY is considered as an oblique wind. The adjusting point(s) should be on the upwind side of the line XY.
3. *Tailwind.* A wind between 1,300 and 1,600 mils of the line XY and blowing from the area to be screened is considered as a tailwind. No adjust-

ing point need be outside the lines DE and FG. The line of adjusting points is upwind of the line XY.

4. *Headwind.* A wind between 1,300 and 1,600 mils of the line XY and blowing toward the area to be screened is considered as a headwind. The direction of the wind is from the enemy towards our own troops; therefore, the smoke mission is likely to be unsuccessful because of the inconvenience caused our own troops by the smoke drifting toward them. If the smokescreen mission is undertaken, the selection of the adjusting point(s) is the same as that for a tailwind, except that the adjusting point must be on the enemy side of the line XY and, in fact, often must be inside the area to be blinded.

13-3. Conduct of Smoke Missions

a. *Types of Smoke Missions.* The method of engagement with smoke varies with the time available and the magnitude of the task. From the point of view of procedure, there are two types of smoke missions—

- (1) The quick smoke mission.
- (2) The deliberate smoke mission.

b. *Observer Procedure for Conduct of the Quick Smoke Mission.*

- (1) *General.* The quick smoke mission is usually satisfactory when the area to be blinded is small, the observer is in the area to be screened, and the wind is from

the flank or nearly so. In such circumstances, the smoke delivered from one gun normally will be sufficient. However, if the observer, after seeing the smoke pattern on the ground, determines that additional points are needed, he will locate these points by coordinates or a shift from the last round fired. Smoke will be delivered on these points and, if necessary, the observer will correct the placement of the smoke.

- (2) *Call for fire.* When the observer desires to smoke an area quickly, he must select the adjusting point upwind from the area to be smoked. The call for fire includes the location of the adjusting point, the direction, the type of smoke mission, the length of the linear target (area to be smoked), the attitude of the target, the estimated number of points needed to adequately cover the target, and the time length of the smokescreen.

Example: FIRE MISSION, GRID 321546, DIRECTION 300, REQUEST SMOKE, 200 METER FRONT, ATTITUDE 4800, ESTIMATE 2 POINTS FOR 30 MINUTES, ADJUST FIRE.

- (3) *Adjustment.* The adjustment is begun on the adjusting point with one gun firing HE with fuze quick. When shell HE has been adjusted to within 100 meters of the adjusting point, the observer will call for smoke to complete the adjustment. The adjustment with smoke is continued until the observer has the proper height of burst (approximately 100 meters) and placement of the smoke on the ground.
- (4) *Fire for effect.* Once fire for effect is begun, the observer must observe the effect of the smoke on the ground to determine if adequate coverage is provided by one adjusting point. If the observer sees that he is not getting the needed coverage, he must select an additional adjusting point(s) with relation to the effect provided from the smoke already on the ground. To determine the number of points needed, the observer divides the width of the area to be blinded by the effective width of the smoke. The observer

may request that the additional point(s) be located accurately by the use of HE and when a 100-meter bracket is obtained switch to smoke. However, if the observer is positive that his location of the additional adjusting point(s) is within 100 meters, he may request smoke be fired immediately and, if necessary, adjust the smoke. Once the observer sees that he is getting adequate coverage, he must notify the FDC as to the length of time he desires the area to be smoked.

c. Observer Procedure for Conduct of the Deliberate Smoke Mission.

- (1) *General.* The deliberate smoke mission is used when the area to be blinded or screened has a longer frontage than can be covered by the fire from a quick smoke mission. The smoke mission may be planned at the FDC and the observer instructed to observe the screen and make any corrections in sheaf, range spread, lateral spread, or rate of fire necessary to provide an adequate smokescreen.
- (2) *Call for fire.* If the observer initiates the deliberate smoke mission, the call for fire will include the same elements as the call for fire for the quick smoke mission. A formal procedure may be impossible because of the number of adjusting points and the large area to be smoked. In this case, many exchanges of information will be informal.
- (3) *Adjustment.* The adjustment is conducted as outlined in b(3) above. The observer evaluates the effect of the smoke on the ground and estimates any corrections necessary to produce an adequate smoke-screen. The situation may arise in which the observer estimates that the entire battery is not required; in this case, he should notify the FDC that the right (left) platoon is not required in fire for effect. Whenever possible, adjustment with HE and fuze quick should be made just prior to the firing of the smokescreen to minimize the effects of any changes in weather.
- (4) *Fire for effect.* Once fire for effect is begun, the observer must observe the effect of the smokescreen to determine if an ade-

quate screen is provided. If the entire area is not screened or gaps are present in the screen, the observer should request any necessary sheaf, range spread, or lateral spread corrections to produce the necessary screen.

Note. The observer must bear in mind that the adjustment of a smoke mission is conducted with HE and fuze quick until rounds are within 100 meters of the desired adjusting point. This is particularly important when it is desired to smoke friendly positions. Great care must be taken to select an adjusting point which will not endanger friendly troops during the HE adjustment.

13-4. White Phosphorus Projectile

White phosphorus (WP) is useful for marking, screening, incendiary, and casualty-producing actions. The adjustment is made with HE and fuze quick. When the adjustment is complete, the observer will call for WP. Fuze quick is used with WP. Action of the fuze and burster charge breaks the projectile and scatters phosphorus particles, which ignite spontaneously on contact with the air. The smoke rises rapidly because of the heat generated by the burning phosphorus. White phosphorus is desirable for marking purposes and

for the immediate buildup of a smokescreen, but, because of the rapid rise of the smoke, WP is not as effective as base-ejection smoke for maintaining a smokescreen. When white phosphorus is used against framehouses or other objects of flammable material, some fuzes should be set at delay to effect penetration before bursting and thus increase the incendiary effect of the burning phosphorus particles. Casualties are effected by the small particles of phosphorus adhering to the clothing and skin, causing painful burns.

13-5. Toxic Chemical Projectiles

Toxic chemical projectiles are fired as authorized by higher authority. Wind speed and direction are always considered so that friendly troops are not unduly endangered. Data for firing toxic chemical projectiles should be the most accurate obtainable. Adjustment should be avoided if at all possible or be conducted on an auxiliary adjusting point with HE to achieve surprise. Either low airbursts or superquick impact bursts are used with toxic chemical projectiles. Weather conditions in the zone of observation are determined by the movement of battle dust and smoke and reported to the FDC (para 24-6).

Section II. BATTLEFIELD ILLUMINATION

13-6. General

The purpose of battlefield illumination is to provide friendly forces with light to assist them in night ground operations, offensive or defensive. The artillery observer is concerned primarily with two means of illumination—illuminating projectiles and searchlights. When properly used, night illumination increases the morale of friendly forces, facilitates operations, and harasses and blinds the enemy. The artillery is responsible for providing illumination with illuminating projectiles and searchlights. Any artillery observer may be called upon to conduct an illumination mission.

13-7. Conduct of Fire Using Illuminating Projectile

a. Uses. Illuminating projectiles are used for—

- (1) Illuminating areas of suspected enemy movements.
- (2) Providing illumination for night adjust-

ment or surveillance of artillery fire by an air or ground observer.

- (3) Harassing the enemy positions or installations.
- (4) Furnishing direction to friendly troops for attacks or patrol activities. (Illumination flares must be placed well in advance of friendly troops to avoid illuminating the troops.)
- (5) Guiding low-level tactical bombers on important targets within artillery range.

b. Ammunition. The following tabulation gives some of the factors to be considered in the employment of artillery illuminating projectiles. Data are approximate and vary with nonstandard conditions.

c. Call for Fire. When the observer desires to illuminate the battlefield using illuminating projectiles, he calls for fire, using the procedures de-

Cannon	Projectile	Initial height of burst (meters)	Distance between bursts (spread) (meters)	Burning time (seconds)	Rate of continuous illumination (rounds per minute)	Rate of fall (meters per second)
105-mm.....	M314A2	750	800	60	2	10
105-mm.....	M314A2E1	750	800	70-75	2	10
155-mm.....	M118	750	800	60	2	10
★155-mm.....	M485	600	1000	150	1	5

scribed in chapters 8 and 9. Elements of the call for fire that require special consideration are—

(1) *Method of engagement.* The size and shape of the area to be illuminated, OT distance, conditions of visibility, and candlepower of the projectile influence the selection of the method engagement. The following methods of engagement may be used:

(a) *One gun.* One round from one gun.

(b) *Two guns.* One round from each of two guns firing simultaneously with the same data and at approximately the same point in the air.

(c) *Two guns, lateral spread.* One round from each of two guns bursting simultaneously at the same range but separated in deflection. (For distance between bursts, see *b* above.) (All spread are made with respect to the GT line.)

(d) *Two guns, range spread.* One round from each of two guns bursting simultaneously but at different ranges along the GT line. (For distance between bursts, see *b* above.)

(e) *Four guns.* One round from each of four guns bursting simultaneously in a diamond pattern (fig. 13-2).

(2) *Type of projectile.* Illuminating must be specified.

(3) *Type of fuze.* Fuze time is used with illuminating projectile. Therefore, this element is omitted from the call for fire.

d. Adjustment.

(1) Range and deviations are adjusted by using standard observed fire procedures, except that the adjustment is considered complete when the illumination is within 200 meters of the desired location. Normally, deviation, range and height of burst are adjusted concurrently. If the height of burst is drastically in error, it may be necessary to adjust the height of burst before adjusting the other elements in order to have enough light to see the target.

(2) The correct relative position of the flare to the adjusting point depends on the terrain and the wind. Generally, the position of the flare should be to one flank of the adjusting point and at about the same range. In a strong wind, the point of burst will have to be some distance from the adjusting point because of the drift of the flare. If the target is on a forward slope, the flare should be on the flank and at a slightly shorter range. If the adjusting point is a prominent target, better visibility may be obtained by placing the flare beyond the target to silhouette it.

(3) The proper height of burst is that which will allow the flare to strike the ground just as it stops burning. Changes in height of burst are made in multiples of 50 meters. The variation in the time of burning of flares renders useless any finer adjustment of the height of burst.

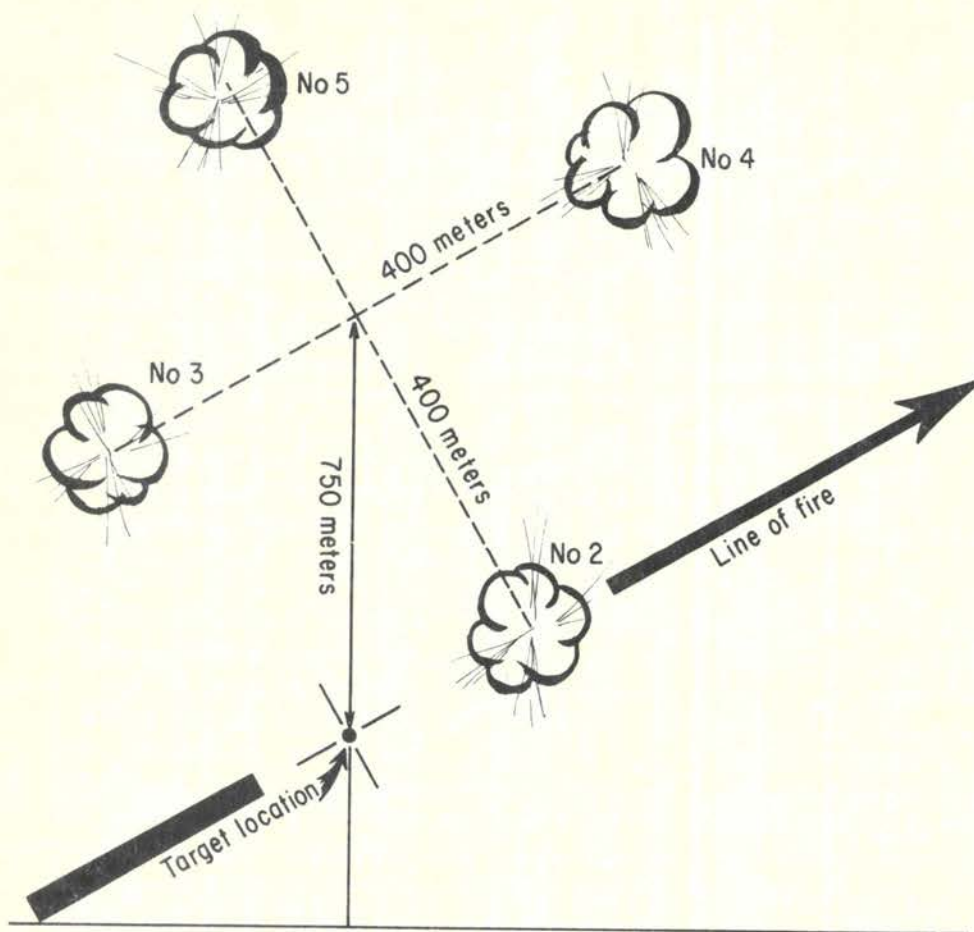
(4) When the point of burst is too high, the height-of-burst change is estimated from the height of the flare as it burned out. When the point of burst is too low, the change required is estimated from the length of time (T) in seconds that the flare burned on the ground. For example, multiplying $T \times 10$ (approximate rate of descent of projectile M118 flare, 10 meters per second), the observer can determine the approximate correction required.

Example: Flare burned 13 seconds on the ground; $13 \times 10 = 130$; the correction is UP 150 (answer rounded off to nearest 50 meters).

(5) After the observer has adjusted the flare to the desired location, he should control the rate of fire and number of pieces firing to reduce ammunition expenditure to the minimum necessary for the required observation.

e. Illumination for HE Adjustment.

(1) If the adjustment of illuminating projectile discloses a suitable artillery target, the observer should request CONTINUOUS IL-



★Figure 13-2. Artillery illumination—four guns.

ILLUMINATION while he adjusts HE fire on the target.

(2) As soon as the observer has located a suitable target for HE fire, he should initiate a normal call for fire. If no better means of designating the location of the target is possible, the burst center of the illumination can be used as a reference point.

(3) If the observer decides to adjust both the illuminating fire and the HE fire concurrently, he prefaces the corrections pertaining to illumination with the word ILLUMINATING and those pertaining to HE with the letters HE; for example, ILLUMINATING, ADD 200; HE, RIGHT 60,

ADD 200. This method usually requires an at my command method of control.

- (4) If the HE adjustment is made on an immobile target, such as a disabled tank or a bridge under construction, the observer may be able to conserve illuminating ammunition by coordinating illumination with the adjustment of HE. The observer requests COORDINATED ILLUMINATION instead of continuous illumination and requests control to be BY SHELL, AT MY COMMAND. This indicates that both HE and illuminating rounds will be fired only at the observer's command. As soon as the FDC reports that illuminating and HE fires are ready, the observer commands the firing of the illuminating round and then gives the command to fire the HE round so that the rounds will arrive during the period of maximum illumination of the target. As an alternate method, the observer may command only the firing of illuminating rounds and allow the FDC to command the firing of HE. During the initial adjustment of the illumination, the observer announces "ILLUMINATION MARK" to the FDC at the exact time of best target illumination. The FDC times the interval between the actual firing of the illuminating round and receipt of the observers "ILLUMINATION MARK." By comparison of this time interval with the time of flight of the HE, the FDC can command the firing of the HE so as to arrive at the target during the period of maximum illumination.

f. Example Mission. See paragraph 14-5 for an example mission.

13-8. Conduct of Fire Using Searchlight Illumination

a. The primary use of searchlights by the observer is illumination of areas of suspected enemy movement and night adjustment or surveillance of artillery fire from air or ground observation posts. Searchlights are also used to guide friendly elements, mark coordinating lines, mark targets for close air support missions, and illuminate objectives in an attack.

b. The number of lights used in any mission will depend on the number available and the situation at that particular time. Normally, when direct illumination is used, a single light will suffice.

c. The observer procedure for the adjustment of the searchlight beam is similar to that employed in a fire mission. However, the observer makes the adjustment on the searchlight-target line in deviation and site. The correction is made in one of two ways. The observer can move the beam in meters right or left and up or down, or the observer can move the beam in whole beam widths or segments of a beam width. In most cases, the beam-width method is simpler and faster for the observer, since his yardstick is the width of the beam itself. The width of the focused (pencil) beam is 52 mils and the width of the spread beam is 180 mils. The width of the focused (pencil) beam is 9 to 13 mils and the width of the spread beam is 125 mils for the 23-inch Xenon searchlight. Examples of observer corrections for a 30-inch searchlight are—

- (1) RIGHT 100 or RIGHT 2 BEAMS.
- (2) UP 20 or UP $\frac{1}{2}$ BEAM.

d. The smallest correction in meters which can be made by the observer is 20 meters. In the beam-width method, the smallest correction is a quarter beam-width shift. It is not necessary to give a change in both deviation and elevation each time an adjustment is desired; it is necessary to give only the element to be corrected. The omission of the other element indicates it is to remain the same. If it is desirable to change the degree of beam spread, the terms used as SPREAD BEAM or FOCUSED BEAM. This correction precedes the elevation and deviation corrections.

e. Elements of the illumination request are as follows:

- (1) *Identification of observer.* Identification of the observer for an illumination mission is the same as that for a call for fire. The warning for a searchlight mission is ILLUMINATION MISSION. Since this term is used only for a searchlight mission, it alerts all personnel involved to pass the mission to the searchlight light direction center (LDC). The LDC normally is collocated with the division (corps) artillery fire direction center. Operators in the communication network

must be familiar with this warning signal and the action to be taken.

- (2) *Target location.* The target may be located by any of the methods described in chapter 8.
- (3) *Description of target.* Description of the target is preceded by the word SUSPECTED if identity of the target cannot be made. If the target is identified, the procedure is the same as that for a call for fire. This report will enable the LDC personnel to determine the priority of missions.

(4) *Method of engagement.*

- (a) *Type of adjustment.* If the type of adjustment is omitted in the call for fire, the observer will receive one light in adjustment. The observer may request two or more lights if he desires.

- (b) *Type of illumination.* The observer has a choice of direct or indirect illumination. Direct illumination requires a clear line of sight between the searchlight and the target. Visibility into the illuminated area is nearly equivalent to daylight observation if the light source is behind the observer. With a single beam shining at a low angle of elevation, deep shadows are cast by brush and other small objects. Intersecting beams may be used to eliminate shadows in the immediate target area. Direct illumination eases control; it is, however, more vulnerable to enemy fire than indirect illumination. With direct illumination, there is a possibility of impairing the night vision of friendly forces and of silhouetting friendly troops and installations. The observer must avoid both of these situations. If the observer does not specify INDIRECT ILLUMINATION, it will indicate that he desires direct illumination. If indirect illumination is requested, the observer will receive light which utilizes the scattered

or reflected light rays from the main searchlight beams. The diffused light of indirect illumination reaches into hollows, draws, and treelined roads. An observer in an area illuminated by diffused light can detect with the naked eye a man standing at ranges up to 150 meters; with the aid of fieldglasses, he can detect a man moving at considerably greater ranges. Indirect illumination can be employed for longer periods of time than direct lighting, because the light source is less vulnerable to enemy interference.

- (c) *Degree of beam spread.* Since the width of the searchlight beam can be either a focused (pencil) beam or a spread beam, the beam spread is included in the call for fire so that the observer can illuminate as large an area as possible commensurate with his observing range capability. The degree of beam spread is designated as FOCUSED BEAM or SPREAD BEAM. If the observer omits this element, a focused beam will be used.

- (5) *Control.* ADJUST LIGHT is the only method of control used with searchlights. If the observer desires to control the time of turning the light on, he may include AT MY COMMAND immediately preceding ADJUST LIGHT. To prevent personnel from misinterpreting fire commands the observer uses the command FLICK to turn on the lights.

f. Some of the terms used in an illumination mission that are not common to field artillery are—

- (1) FLICK—Put light in action (corresponds to command FIRE).
- (2) ACTION COMPLETE—Pointing data have been set on light (corresponds to command SHOT).
- (3) CUT—Put light out of action.
- (4) HOLD—Light is on target.

g. See paragraph 14-6 for an example mission.

Section III. CONDUCT OF ASSAULT FIRE

13-9. General

a. Assault fire is a special technique of indirect fire in which the maximum charge which will clear intervening crests is used, thus effecting maximum muzzle velocity and penetration. Firing is conducted at a short range from a defiladed weapon position to attain pinpoint accuracy against a stationary target. The short range and flat trajectory make possible successive hits on the same portion of the target. Only one gun is used on a mission, and the FDC for the mission normally is located at or near the weapon position.

b. Assault fire is used for the destruction of caves, pillboxes, or other fixed fortifications by firing on the vertical portion of the target.

c. See paragraph 14-7 for an example mission.

13-10. Ammunition Used for Assault Fire

a. *Projectile.* An HE projectile is used for assault fire.

b. *Fuzes.* Concrete-piercing fuze is appropriate for destroying fortifications. Fuze quick is used for adjusting and for cutting through a parapet or earth covering. Then concrete-piercing delay fuze or fuze delay is used in fire for effect to effect penetration and destruction. If excessive ricochets result from the use of concrete-piercing delay fuze, concrete-piercing nondelay fuze should be used until enough cratering has been effected to prevent ricochet of the delay fuze. Also, concrete-piercing nondelay fuze may be used to clear away rubble during the fire for effect.

13-11. Preparatory Operations

The observer and all personnel concerned with an assault fire mission should prepare detailed plans for the mission. Thorough planning, reconnaissance, and coordination must be completed before the weapon position is occupied. The observer must occupy an observation post as near the target as possible and on or near the gun-target line.

13-12. Initial Data

Normally, initialed data are prepared in advance by use of the best means available (usually survey) to locate the target with respect to the assault weapon position. Therefore, in most cases, a complete call for fire from the observer is not necessary.

13-13. Adjustment

Adjustment is made by using a modified procedure in which the observer exercises complete control of fire throughout the mission. Corrections in meters are given by the observer for each successive round until the point of impact is on the desired portion of the target. An off-line burst is corrected to bring subsequent bursts to the line through normal adjustment procedure except that deviation corrections should be given to the nearest meter. The target is bracketed for range, and the bracket is split successively.

13-14. Fire for Effect

a. When the observer splits a 50-meter range bracket, he is in fire for effect although no announcement of fire for effect is made. At this time the observer normally is able to estimate vertical error more accurately than he can estimate range error. Therefore, the observer makes corrections for altitude rather than range. After a 50-meter range bracket is split, the smallest appropriate correction in direction or altitude is one-half meter. The observer continues to send a correction to the FDC for each round fired. All rounds are fired singly or as requested by the observer to permit the desired corrections or changes in ammunition to be made between rounds. It is the observer's responsibility to control and end the mission.

b. The observer usually will be able to see each round in flight as it travels to the target. The observer will make more accurate spottings by noting the position of the round at the instant before the burst than by judging from the burst itself, which will enable him to make the small corrections necessary to attain pinpoint accuracy.

Section IV. CONDUCT OF FIRE USING COMBINED OBSERVATION

13-15. General

a. Combined observation is that type of observa-

tion in which two or more observers at different locations are employed to obtain spottings on the

same target. For effective conduct of fire using combined observations, the angle of intersection of the OT lines should not be less than 150 mils although 300-500 is preferred.

b. Combined observation is used for the following types of missions:

- (1) High-burst registration.
- (2) Mean-point-of-impact registration.
- (3) Fire to obtain surprise through use of fire-for-effect transfers.
- (4) Surveillance of planned fires.

c. Observation posts should be established during daylight so that instruments may be oriented and a line materialized on the ground for orientation after dark. The OT direction of targets discovered during daylight is recorded by all observers. Targets may be located at night by placing the illuminated crosshairs of an observing instrument on the flash of an enemy weapon. Vertical angle and direction are recorded if adjustment is not started at once. As an expedient, direction to a flash may be materialized on the ground by a piece of white tape or two stakes.

13-16. Equipment

a. To obtain optimum accuracy, each observer should be equipped with a BC scope or an aiming circle.

b. If a line of known direction is not available, initial direction to the target can be obtained by the use of a compass. Subsequent deviations from the OT line can be measured with fieldglasses if a BC scope or aiming circle is not available. However, the use of a compass and fieldglasses for combined observation is inaccurate and may preclude the use of this method of adjustment during darkness.

13-17. High-Burst Registration

a. *General.* At night, visual adjustment of fire on a ground registration point is impossible without illumination. In desert, jungle, or arctic operations, clearly defined registration points in the target areas often are not available. Special procedures have been developed to permit registration under these conditions. One such procedure is a high-burst registration, using time fuze. (For FDC procedures, see para 19-27 through 19-36.)

b. *Orientation of Observer.* In a high-burst registration, two observers (01 and 02) usually are employed. The location of each observer and the

desired point of burst are known at the fire direction center. The fire direction center will determine and furnish to each observer the direction and vertical angle to the expected point of burst. A typical message to the observers from the FDC is as follows:

OBSERVE HIGH BURST. 01 DIRECTION 1164, VERTICAL ANGLE PLUS 12, MEASURE THE VERTICAL ANGLE. 02 DIRECTION 718, VERTICAL ANGLE MINUS 3. REPORT WHEN READY TO OBSERVE.

c. *Conduct of Registration.* Observers 01 and 02 orient their instruments on the direction and vertical angles given and report when ready to observe. (As soon as practicable after orientation of his instrument, the observer will set out, on a known direction, a stake which can be equipped with a light for night orientation.) The S3 directs the firing of one orienting round. The observer will orient the center of the reticle of his instrument on the point of burst. After the orienting round, the observer will not change the orientation of his instrument. Instead, the observed deviation on the reticle is combined with the reading set on the azimuth and micrometer scales to derive the measured direction. The same general procedure is used to measure the vertical angle. Both observers report direction readings, but only the designated observer will report the vertical (e.g., based on the message to the observers in b above, only observers 01 would report vertical angles).

13-18. Mean-Point-of-Impact Registration

A mean-point-of-impact registration is conducted in the same manner as a high-burst registration (para 13-17) except that an impact fuze is used instead of a time fuze.

13-19. Combined Observation for Missions Other Than High-Burst or Mean-Point-of-Impact Registration

a. *General.* At long OT distances (more than 4,000 meters), the use of combined observation may conserve ammunition. Combined observation is especially important for heavy artillery, since observing distances are normally so great that adjustment by using normal procedure is very difficult. (For FDC procedures, see para 24-24 and 24-25.)

b. *Observation Posts Plotted.* If the observation

posts are plotted on the FDC charts, the following procedures apply:

- (1) *Target location and orientation of observation posts.*
 - (a) When an accurate target location is furnished by higher headquarters, the FDC, using the procedures described in paragraph 13-17b, orients the observation posts.
 - (b) When one observer locates the target accurately, the FDC, using the target location, orients the other observer.
 - (c) When one observer locates a target, he may orient the other observer on the location of the target. Both observers may then report directions to the target, and the FDC can locate the target by intersection.
- (2) *Procedure during adjustment.* When both observers report **READY TO OBSERVE**, firing is begun. After each round is fired, each observer reports the direction and the designated observer reports the vertical angle to each burst. If so directed, the observers report deviations (number of mils right or left of the OT line) rather than directions.

13-20. Target Area Base

A target area (short) base (fig. 13-3) may be established to locate targets rapidly and accurately. A target area base consists of two observation posts from which points in the target area can be located by a combination of intersection and polar plotting. Distances are computed, but the targets are placed on the firing chart by polar plotting. The base must be long enough to give an angle of intersection of at least 150 mils at the target. The base should be as nearly perpendicular to the direction to the target area as possible. 01 and 02 should be plotted on the firing chart, and the distance and direction between them determined.

a. When the ends of the base are intervisible, the interior angles at 01 and 02 are measured. If the ends of the base are not intervisible, the interior angles must be computed by comparing the direction of the base with the direction from each observation post to the point being located (FM 6-2).

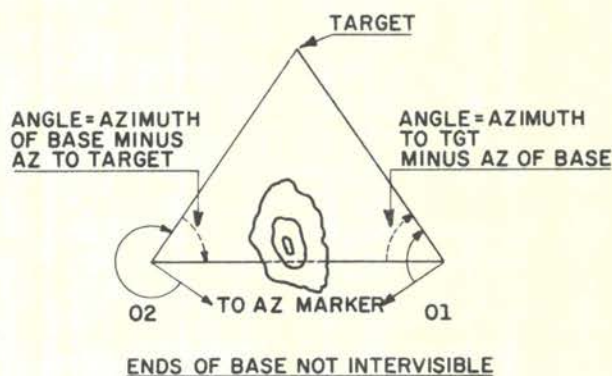
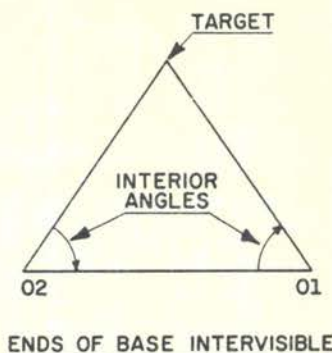


Figure 13-3. Target area (short base).

b. The apex angle (the angle at the target formed by the intersection of the lines of sight from the two observation posts) is determined by subtracting the sum of the interior angles at 01 and 02 from 3200.

c. The distance from 01 to the target is solved by using the law of sines, as follows:

$$\frac{\text{Distance 01 to target}}{\sin \text{ angle at 02}} = \frac{\text{length of base}}{\sin \text{ apex angle}}$$

When the law of sines is applied, the supplementary angle may be substituted for the interior angle at 02, since the sines of supplementary angles are equal.

d. The military slide rule is arranged to provide a rapid and simple solution to the short base problem. The steps in the solution are as follows:

- (1) Place the hairline of the cursor over the value of the angle at 02 on the scale marked "opposite angle."
- (2) Move the slide until the value of the apex angle of the scale marked "apex angle" is under the hairline.
- (3) Move the cursor until the hairline is over

the length of the base on the C (base) scale.

- (4) Read the distance from 01 to the target on the D (range) scale.

e. The target location is reported to the FDC by polar coordinates from 01 as **DIRECTION** (so much), **DISTANCE** (so much), **UP** (**DOWN**) (so much).

Section V. ADJUSTMENT OF HIGH-ANGLE FIRE AND AUXILIARY ADJUSTING POINT

13-21. General

a. Fire delivered at elevations greater than the elevation for maximum range is called high-angle fire. High-angle fire is often required when the weapons fire out of deep defilade, from within cities, or over high terrain features near friendly troops. High-angle fire may also be required when targets are located directly behind hill crests, in jungles, or in deep gullies or ravines and cannot be reached by low-angle fire.

b. Most artillery weapons are capable of high-angle fire. Generally, those cannon which have a maximum elevation substantially in excess of 800 mils have the capability of firing high-angle fire.

13-22. Determining Requirements for High-Angle Fire

Usually, an observer can determine whether high-angle fire is required for any given target; if he cannot determine this, he notifies the FDC that high-angle fire may be necessary. In that case, the S3 decides whether high-angle fire is to be used and notifies the observer that it will be used.

13-23. Call for Fire

a. When high-angle fire is desired, the observer so indicates in his call for fire.

b. An accurate initial location of the target is desirable. Large shifts during adjustment may necessitate a change of charge, which could introduce a loss of time and accuracy.

c. The excessive height of burst probable error associated with a long time of flight makes time

fire undesirable. Because of the steep angle of fall, ricochet fire is seldom possible.

d. Quick and VT fuzed projectiles give excellent effect from side spray because of the steep angle of fall. VT fuzes produce a lower height of burst than normally obtained with low-angle fire.

13-24. Adjustment

a. The observer procedure for the adjustment of high-angle fire is the same as that for low-angle fire.

b. The observer must realize that small deviation corrections during adjustment may be unnecessary and time consuming because of increased dispersion experienced during high-angle fire.

c. Since the time of flight is long in both adjustment and fire for effect, the FDC will announce **SHOT** when the round(s) is fired and **SPLASH** 5 seconds before the burst(s) occurs. Air observers are also given **TIME OF FLIGHT** (so much) after the message to the observer.

13-25. Auxiliary Adjusting Point

In order to achieve surprise, the observer may decide not to adjust on the target but to adjust on a nearby point. This nearby point, the auxiliary adjusting point, must be far enough away from the target that the real purpose of the adjustment is obscured. At the same time, the auxiliary adjusting point must be so selected that an accurate shift to the target may be determined. When the adjustment on the auxiliary adjusting point is complete, the shift to the target is made.

Section VI. CONDUCT OF FIRE WHEN OBSERVER IS NOT ORIENTED

13-26. General

In a rapidly moving situation, an observer may become confused and disoriented. An observer in a moving tank has a problem in orientation because his OT direction is constantly changing. To bring fire upon a target when the direction is changing rapidly or is unknown requires that both

the observer and the FDC exercise judgment and initiative.

13-27. Target Location

If possible, the target location is determined by using the procedures prescribed in chapter 8. If target location by normal means is not possible, the observer must request that a round be fired

at a point where he can identify it and use that round as his known point.

13-28. Gun-Target Line Method of Adjustment

When the observer cannot determine the OT direction or when the OT direction is changing frequently, for example, when the observer is with a

tank unit, the observer may decide to adjust with respect to the gun-target line. To determine the direction of the GT line, it may be necessary to request ranging rounds (two rounds fired at the same deflection but 400 meters apart in range). When the observer is adjusting with respect to the GT line, the S3 should select a unit to fire whose location will result in the smallest angle T.

Section VII. ADJUSTMENT OF FIRE BY SOUND

13-29. General

During operations when observer visibility is restricted, fire may be placed on an enemy location by the use of sound alone.

13-30. Adjustment of Fire by Sound

a. Target Location. Target locations may be reported to the observer by the supported unit or be determined by the observer. If the observer can hear noises at the enemy position (weapons firing, vehicles, troop movement, etc.), he can estimate a direction and distance from his position.

b. The Call for Fire. When adjustment by sound is to be used, the observer so indicates in the call for fire. If troop safety is involved, the call for fire must produce data that are safe.

c. Adjustment.

(1) Only one gun is used in the adjustment. Upon hearing the burst of the adjusting round, the observer estimates the direction to the burst and compares it to the direction to the target. The deviation is converted to a lateral shift in meters by using the estimated distance from the observer's position to the target.

(2) Distance to the adjusting burst is difficult to judge; therefore, it may be necessary for the

observer to use creeping techniques to adjust onto the target. Distance can be determined by measuring the time that it takes for the sound of the burst to reach the observer and multiplying the time interval by the speed of sound, which is 340 meters per second. (In this case, the time of impact must be announced by the fire direction center.)

(3) Caution must be exercised by the observer in very broken terrain. In hills or mountains the sound may have traveled around a hill mass before arriving at the observer, thus producing a false direction to the burst. If this occurs, it may be necessary to fire a high airburst (s) initially.

d. Adjustment With More Than One Observer.

(1) A more accurate target location can be derived if two or more observers can hear the noises produced at the enemy location. Each observer reports an estimated direction to the enemy location. The FDC can plot the data and determine the round location by intersection.

(2) During the adjustment, each observer reports the direction to the burst and the FDC plots the data. The FDC uses intersection to determine the impact point of the round and applies the appropriate corrections to the subsequent round to bring it to the target.

Section VIII. AERIAL FIELD ARTILLERY

13-31. Adjustment

The adjustment of aerial field artillery is a responsibility of the forward observer. Adjustment procedures may be found in FM 6-102.

CHAPTER 14

ILLUSTRATIVE EXAMPLES

14-1. General

The examples of missions contained in this chapter are typical of those that an observer may be called upon to fire. In the examples in paragraphs 14-2 through 14-7, the symbols indicate the following: + = Spotting of *OVER*.

— = Spotting of *SHORT*.

? = Spotting of *DOUBTFUL*.

14-2. Precision Registration

Target: surveyed registration point; mission: registration; materiel: 155-mm howitzer; ammunition: shell HE with fuze quick.

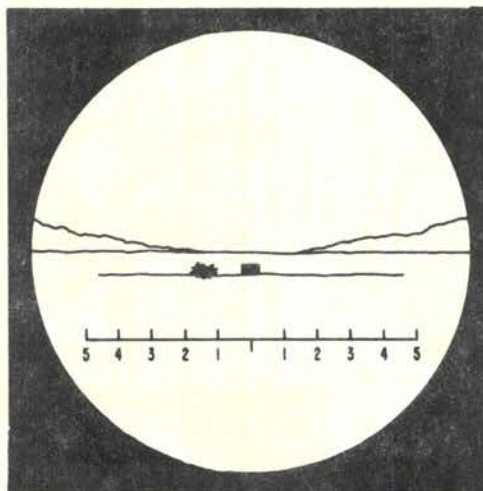
Messages, corrections, and commands
 Observer to FDC (call for fire)
 FIRE MISSION, REGISTRATION
 POINT 1, DIRECTION 4710,
 REGISTRATION, ADJUST FIRE.
 FDC will transmit to the
 observer those elements
 of interest to him.
 FDC to observer: SHOT.

Results

Observer Spottings

Re Dev

? 15L



Remarks: Estimated OT distance = 3,000 meters. With field glasses, observer measured deviation (dev) of burst 15 mils left of OT line. Observed deviation = 45 meters (15 X 3). No range spotting is obtained. Observer determines shift of right 40 (45 rounded to the nearest 10 meters) to bring the next burst to the OT line.

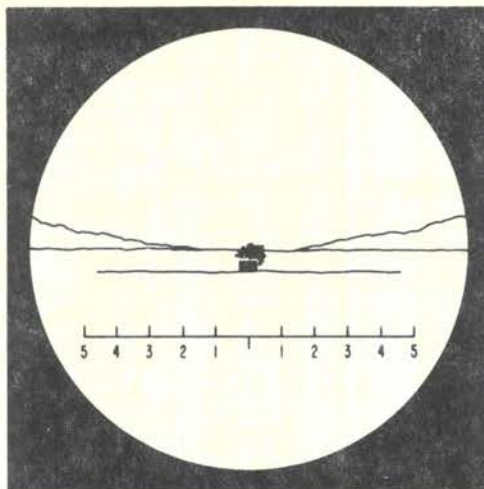
Figure 14-1. Spotting the burst in impact registration.

Messages, corrections,
and commands

Observer to FDC:

RIGHT 40.

FDC to observer: SHOT.

ResultsObserver SpottingsRgDev

+

Line

Remarks: The burst has been brought to the OT line. From this spotting of OVER, the observer decides to make a range change of 200 meters.

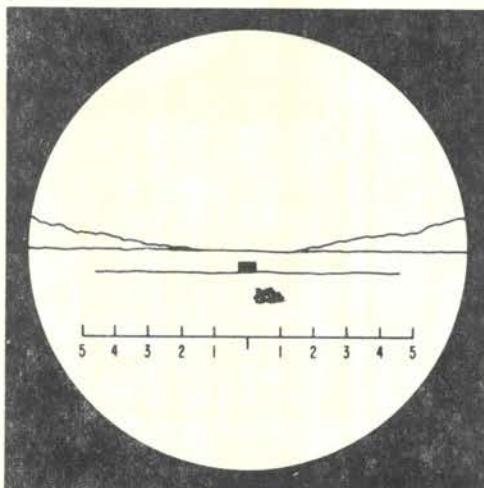
Figure 14-1—Continued.

Messages, corrections,
and commands

Observer to FDC:

DROP 200.

FDC to observer: SHOT.

ResultsObserver SpottingsRgDev

-

5R

★ Figure 14-1—Continued.

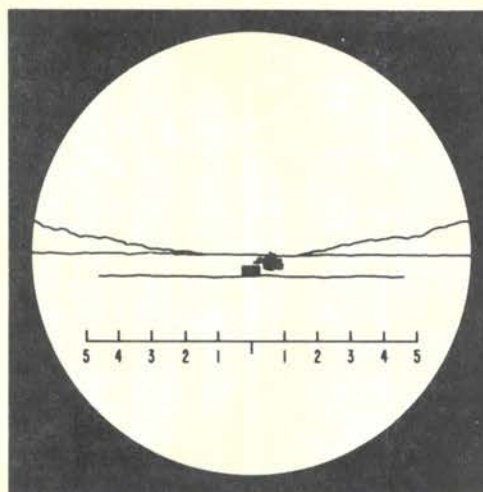
Messages, corrections,
and commands

Observer to FDC:

LEFT 20 ADD 100.

FDC to observer: SHOT.

Results



Observer Spottings

Rg

Dev

+

Line

Remarks: A 100-meter bracket has now been obtained along the OT line. With the next round, the observer will request a change of 50 meters which will be the first round in fire for effect.

Figure 14-1—Continued

Messages, corrections,
and commands

Observer to FDC:

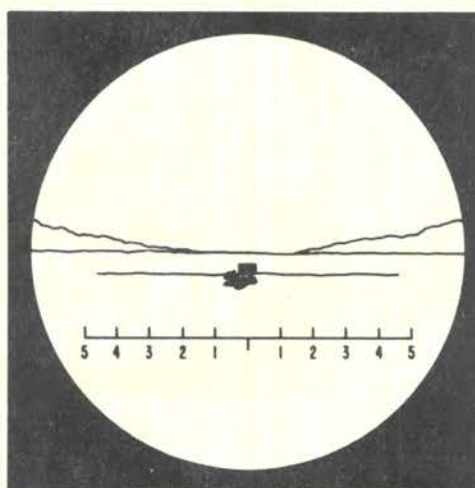
DROP 50, FIRE FOR EFFECT.

FDC to observer: SHOT.

Observer to FDC:

SHORT, LINE.

Results



Observer Spottings

Rg

Dev

Line

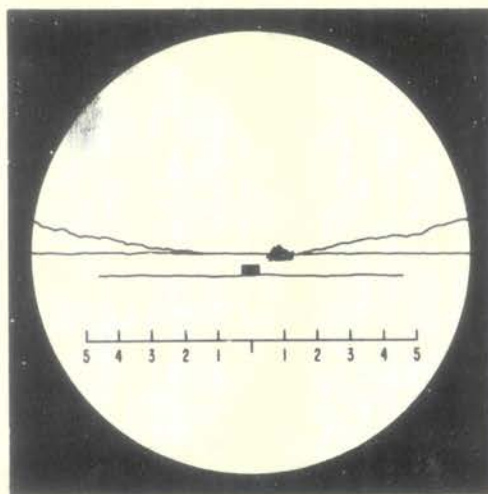
Remarks: No further corrections by the observer are given. The S3 assumes control and continues the mission until he has sufficient spottings from which to compute an adjusted elevation. The observer reports only his spottings.

Figure 14-1—Continued

Messages, corrections,
and commands

FDC to observer: SHOT.
Observer to FDC:
OVER, RIGHT.

Results



Observer Spottings

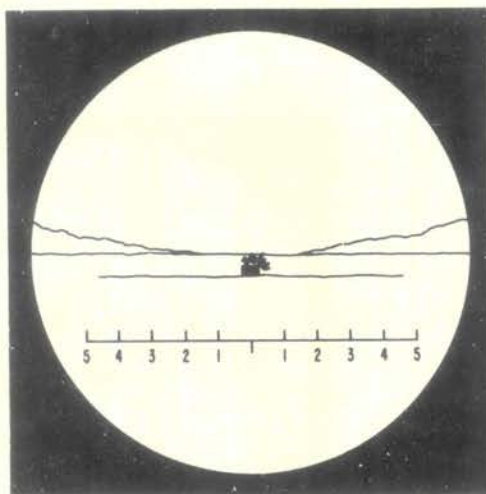
<u>Rg</u>	<u>Dev</u>
+	Right

Figure 14-1—Continued

Messages, corrections,
and commands

FDC to observer: SHOT.
Observer to FDC:
OVER, LINE.

Results



Observer Spottings

<u>Rg</u>	<u>Dev</u>
+	Line

Figure 14-1—Continued

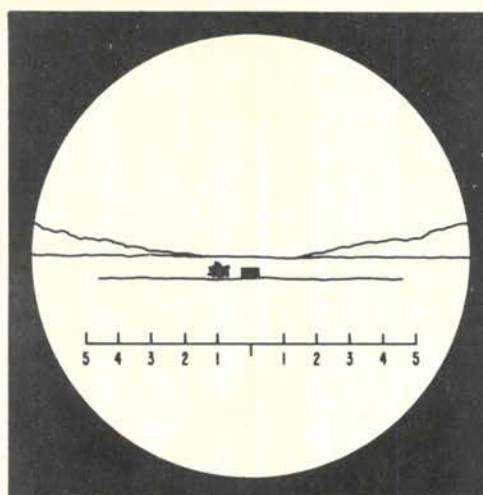
Messages, corrections,
and commands

FDC to observer: SHOT.

Observer to FDC:

DOUBTFUL, LEFT.

Results



Observer Spottings

<u>Rg</u>	<u>Dev</u>
?	Left

Remarks: This round is not on the OT line. The observer spots the round as DOUBTFUL, LEFT.

Figure 14-1—Continued

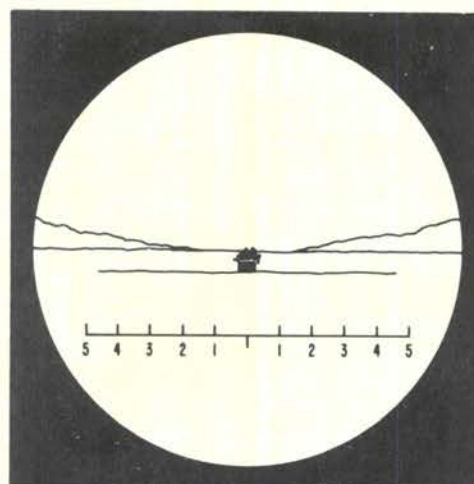
Messages, corrections,
and commands

FDC to observer: SHOT.

Observer to FDC:

OVER, LINE.

Results



Observer Spottings

<u>Rg</u>	<u>Dev</u>
+	Line

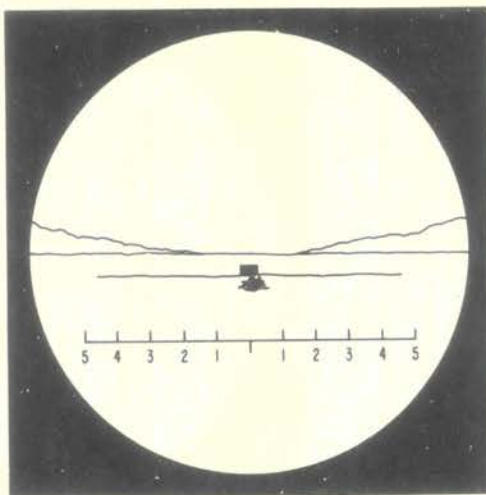
Figure 14-1—Continued

Messages, corrections,
and commands

FDC to observer: SHOT.

Observer to FDC:

SHORT, LINE.

ResultsObserver SpottingsRgDev

-

Line

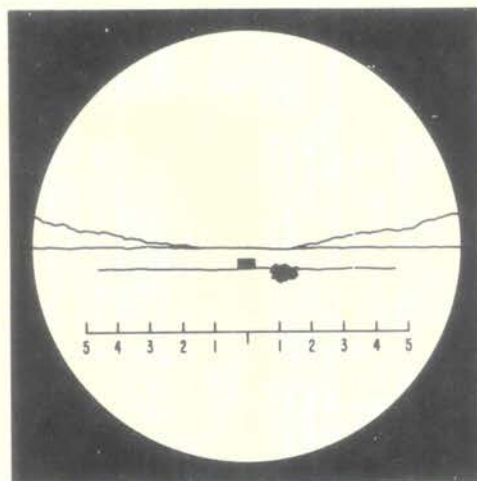
Figure 14-1—Continued

Messages, corrections,
and commands

FDC to observer: SHOT.

Observer to FDC:

SHORT, RIGHT

ResultsObserver SpottingsRgDev

-

Right

Remarks: The S3 has now obtained six usable spottings and, terminates the mission.

Messages, corrections,
and commands

FDC to observer:

END OF MISSION.

Figure 14-1—Continued

14-3. Time Registration

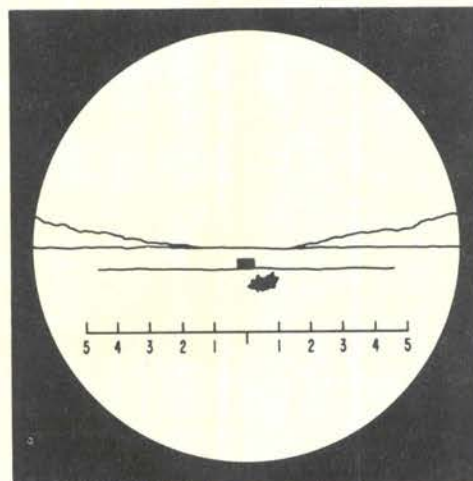
Target: registration point; mission: time registration (it is assumed that the observer has just completed a precision registration on the

registration point); materiel: 155-mm howitzer; ammunition: shell HE, fuze time (fig. 14-2).

Messages, corrections, and commands
 FDC to observer:
 OBSERVE TIME REGISTRATION,
 SHOT.
 Observer to FDC: GRAZE.

ResultsObserver Spottings

G

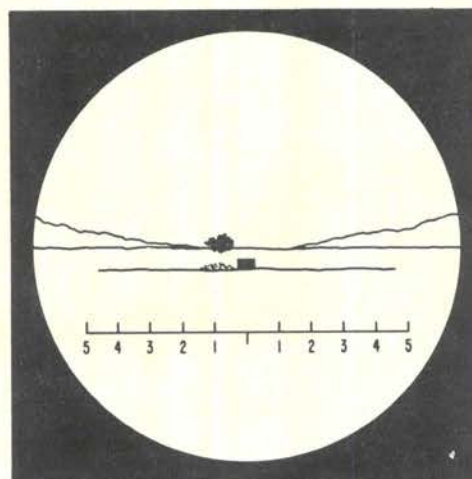


★Figure 14-2. Spotting the burst in time registration.

Messages, corrections, and commands
 FDC to observer: SHOT.
 Observer to FDC: AIR

ResultsObserver Spottings

A



★Figure 14-2—Continued.

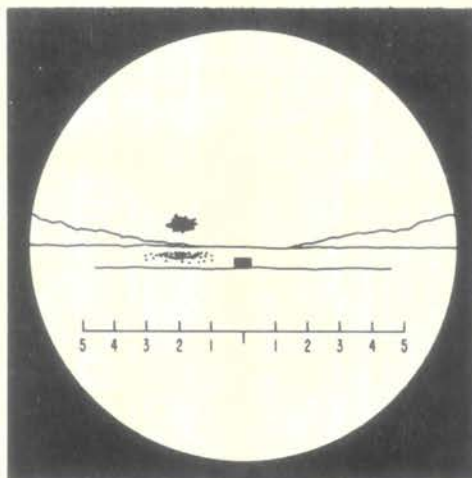
Messages, corrections,
and commands

FDC to observer:
OBSERVE 3 ROUNDS, SHOT.

Results

Observer Spottings

A



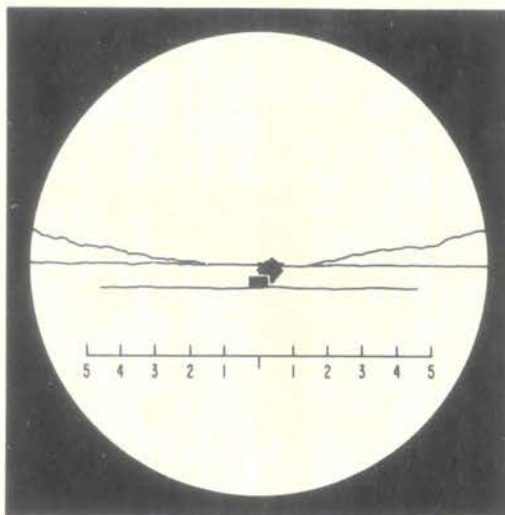
★Figure 14-2—Continued.

Messages, corrections,
and commands

Results

Observer Spottings

G



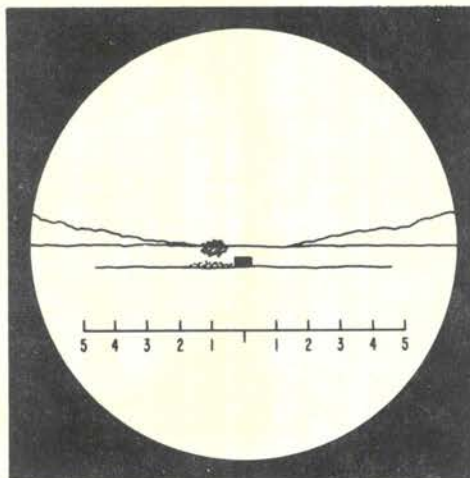
★Figure 14-2—Continued.

Messages, corrections,
and commands

FDC to observer:
 ROUNDS COMPLETE.
 Observer to FDC:
 AIR, GRAZE, AIR.

ResultsObserver Spottings

A



Remarks: Two more rounds will be fired at the graze end of time bracket to obtain six time spottings.

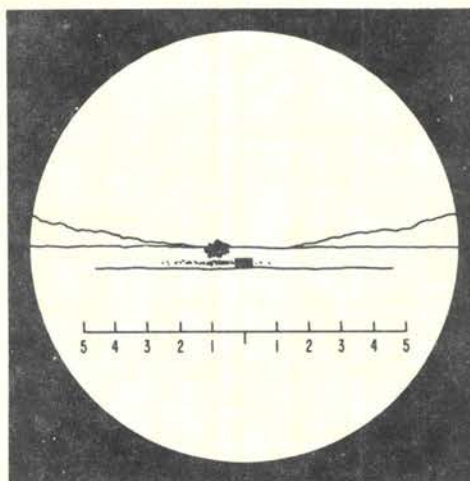
★Figure 14-2—Continued.

Messages, corrections,
and commands

FDC to observer:
 OBSERVE 2 ROUNDS,
 SHOT.

ResultsObserver Spottings

A

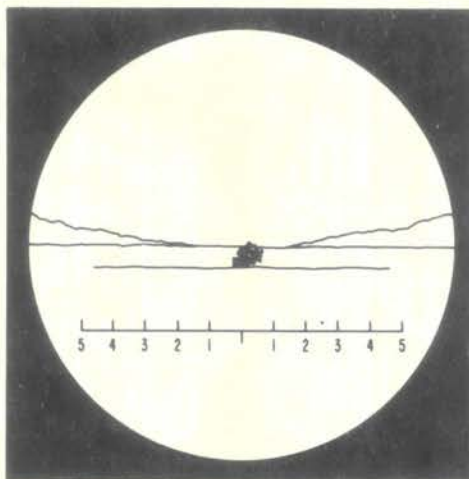


★Figure 14-2—Continued.

Messages, corrections,
and commandsResultsObserver Spottings

FDC to observer:
 ROUNDS COMPLETE
 Observer to FDC:
 AIR, GRAZE.

G

Messages, corrections,
and commands

FDC to observer:
 END OF MISSION

★Figure 14-2—Continued.

★14-4. Area Mission

Target: machineguns; mission: neutralization;
 materiel: 155-mm howitzer; ammunition: shell
 HE (both quick and time fuzes in battery).
 Shift from registration point (fig. 14-3).

14-5. Coordinated Illumination Mission

a. An observer hears a number of heavy vehicles at a direction estimated at 5,800 mils. He cannot detect any lights and the entire area is in complete darkness. Judging from the sound and the map study, the observer estimates the source of the noises to be grid 725365, which is about 2,000 meters from his position. He sends the following call for fire: BOLD RANGE 18, THIS IS BOLD RANGE 24, FIRE MISSION, GRID 725365, DIRECTION 5800, VEHICLE NOISES, SUSPECTED TANKS, ILLUMINATING, LATERAL SPREAD, 2 GUNS, ADJUST FIRE.

b. The first rounds of M118 illuminating projectiles burst about 100 mils left of the suspected area and 150 meters too high. The observer requests—

RIGHT 200, DOWN 150.

c. The second group of rounds burst short near the OT line but too low—the rounds burn 5 seconds on the ground. The observer requests—

ADD 400, UP 50.

Note. The time of burning (T) on the ground 5 seconds) times the rate of descent (10 meters per second).

d. The third group of rounds bursts over the suspected area at the correct height and the observer notices two tanks and a number of infantry moving out to the right at the extreme right edge of the illuminated area. He determines a shift from the center of the illumination and transmits the following:

RIGHT 400, COORDINATED ILLUMINATION, GRID 73113690, DIRECTION 6100, 2 TANKS AND PLATOON OF INFANTRY, VT IN EFFECT, BY SHELL, AT MY COMMAND, ADJUST FIRE.

e. The observer is notified when HE is ready and when illuminating is ready and will control the firing so that the HE will arrive during the period of maximum illumination of the target. The corrections for the first rounds in the adjustment of HE are as follows:

Messages, corrections
and commands

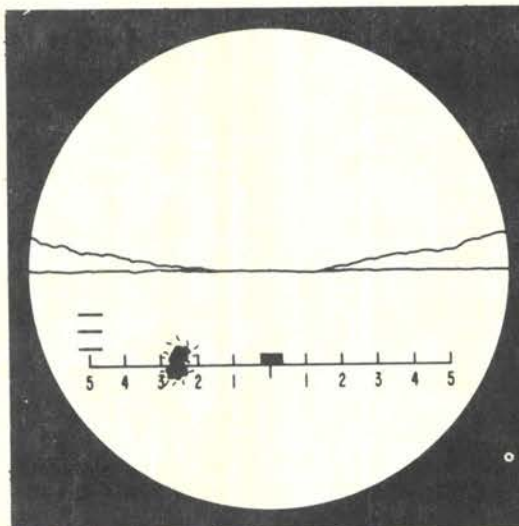
Results

Observer
Spottings
Rg Dev

Observer to FDC:

FIRE MISSION, FROM REGISTRATION POINT 1, DIR 1880, LEFT 660, DROP 1000, MACHINEGUNS, TIME IN EFFECT, ADJUST FIRE. FDC will transmit to the observer those elements of the fire order of interest to him.

FDC to observer: SHOT



? 25L

Remarks: Estimated OT distance = 2,200 meters. With field glasses observer measures deviation of burst center as 25 mils left of the OT line. Observed deviation = 50 meters (25 X 2). No range spotting is obtained.

★Figure 14-3—Area mission using fuze time.

ILLUMINATING, REPEAT; HE, LEFT 70, ADD 100.

f. The observer's request to fire for effect is ILLUMINATING, REPEAT; HE, RIGHT 10, DROP 50, FIRE FOR EFFECT. He retains control of the time of firing to observe the effect.

g. The tanks and remaining infantry are moving out to the northwest away from the observer. It is necessary to shift illumination, and the observer desires to repeat fire for effect against the target. He requests—

ILLUMINATING, ADD 400; HE, LEFT 50 REPEAT.

h. The tanks and infantry have moved out of the observation capabilities of the observer. He reports—

RECORD AS TARGET, END OF MIS-

SION, TANKS AND INFANTRY DISPERSED TO NORTHWEST.

14-6. Searchlight Mission

a. The observer hears movement and suspects an attempt is being made to repair a disabled tank which is blocking a road in his sector. Searchlights are available, and a study of the terrain indicates that it is possible to illuminate the tank directly. He sends the following mission:

EVER READY 18, THIS IS EVER READY 24, ILLUMINATION MISSION, GRID 67184437, DIRECTION 780, SUSPECTED ACTIVITY AROUND DISABLED TANK, TWO LIGHTS, ADJUST LIGHTS.

b. The left beam appears below the target, and the right beam is two beam widths to the

Messages, corrections,
and commands

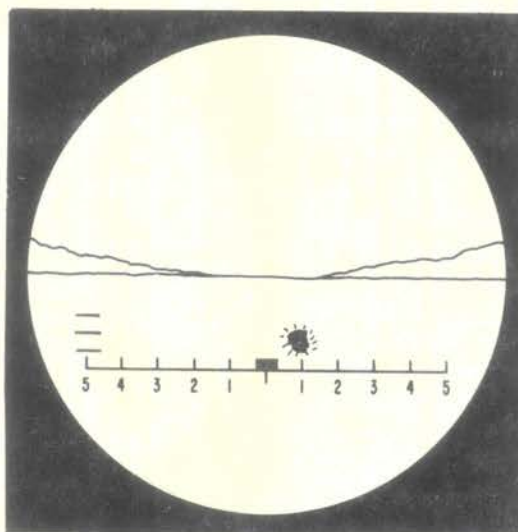
Observer to FDC:
RIGHT 50

FDC to observer: SHOT

Results

Observer
Spotting
Rg Dev

+ 10R



Comment: Deviation of 10 mils converts to 20 meters. This is a minor deviation. The observer elects to ignore it inasmuch as he is able to obtain a range spotting. If a range spotting were not obtainable, this deviation would be corrected.

★Figure 14-3—Continued.

left. The observer requests NUMBER 1, RIGHT 2 BEAMS: NUMBER 2, UP $\frac{1}{2}$ BEAM.

c. Both beams having been centered on the target, the observer orders HOLD. The command HOLD causes the lights to be held on the target and allows the observer to call for a destruction mission on the tank. After the tank is destroyed, the observer will terminate the mission as indicated below:

END OF MISSION, STALLED TANK DESTROYED.

d. If, in the course of the HE mission, the observer decides it is better to cut off the lights but wants to hold the position of the lights, he requests HOLD, CUT. To restore light to the target, he requests FLICK.

e. Using these commands, together with artillery fire at his command, the observer is able to light the target for adjustment and surveillance and hold to a minimum the exposure of friendly light positions.

14-7. Assault Fire Mission

Target: cave in hard rock of hillside; mission: to seal cave entrance; materiel: 8-inch howitzer; gun-target range: 1,500 meters; observer-target distance: 1,000 meters. The mission has been prearranged in detail, and a complete call for fire is unnecessary. The observer reports when he is ready to observe, and the FDC, having prepared all data in advance, sends commands to the howitzer to fire the first round. Since the first round is fired at such

Messages, corrections,
and commands

Results

Observer
Spottings
Rg Dev

Observer to FDC:
DROP 200

FDC to observer: SHOT

10R

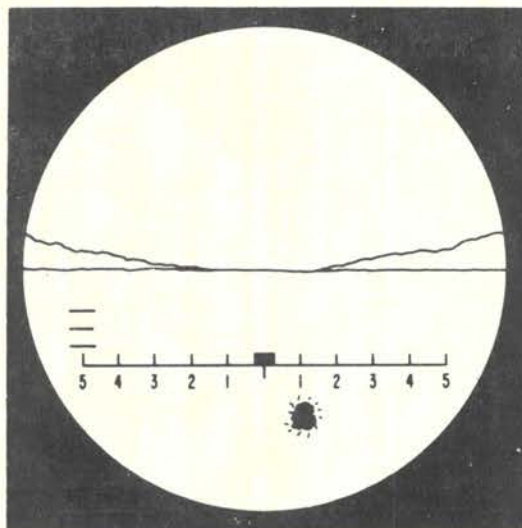


Figure 14-3—Continued.

Messages, corrections,
and commands

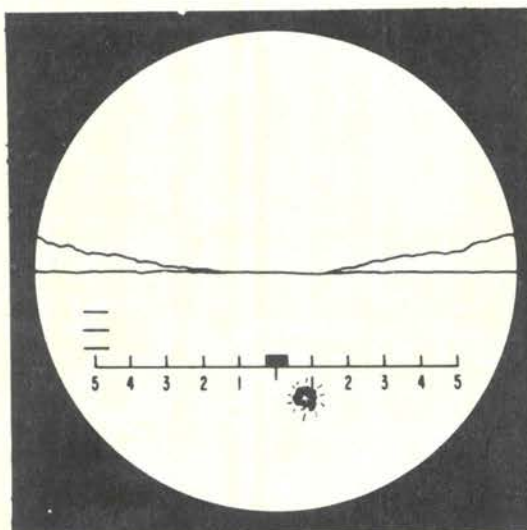
Results

Observer
Spottings
Rg Dev

Observer to FDC:
ADD 100

FDC to observer: SHOT

10R



★ Figure 14-3—Continued.

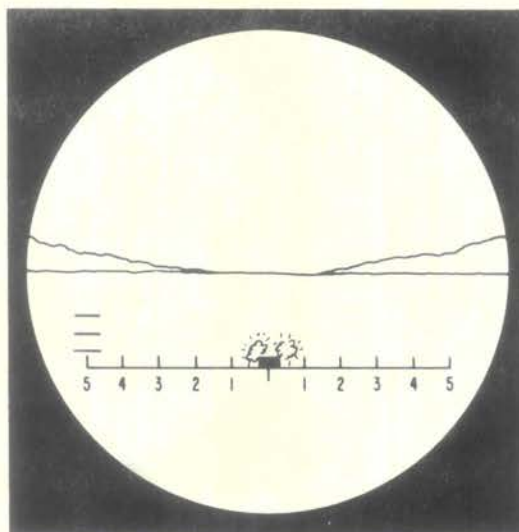
Messages, corrections,
and commands

Results

Observer
Spottings
HOB

Observer to FDC:
TIME, L20, ADD50

FDC to observer: SHOT



A

Remarks: The observer spotting of AID 5 mils permits the HOB to be adjusted to 25 meters and fire for effect requested.

Figure 14-3—Continued.

short range with precise initial data, it should be close to the target.

Remarks	Observer Corrections	Remarks	Observer Corrections
First round burst 10 mils right of OT line, doubtful for range.	LEFT 10.	Fifth round bursts at left edge just below cave entrance.	RIGHT ½, UP ½.
Second round burst between observer and target.	ADD 50.	Sixth round is in cave entrance. Fuze CP delay is now appropriate to penetrate hard rock.	CONCRETE-PIERCING DELAY, REPEAT.
Third round bursts beyond target.	DROP 25.	Seventh round also bursts in cave entrance. Cave is now almost completely sealed.	REPEAT.
Fourth round bursts just above upper right corner of cave entrances. (Changes in height instead of range are now appropriate.)	LEFT 1, DOWN 1.	Eighth round strikes cave entrance, completely sealing it with rubble.	END OF MISSION, CAVE ENTRANCE SEALED.

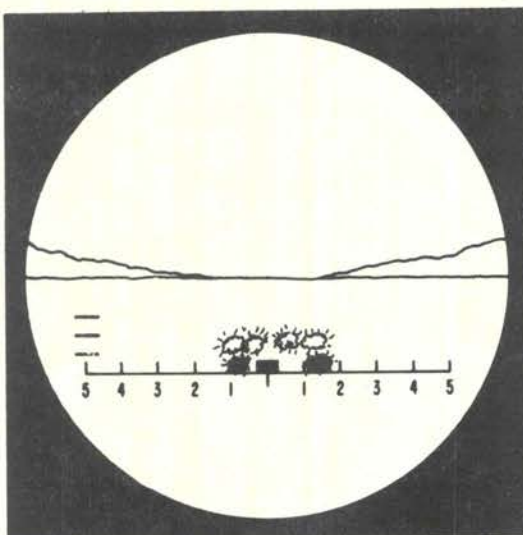
essages, corrections,
and commands

Results

Observer
Spottings
Rg Dev HOB

Observer to FDC:
UP 10, FIRE FOR EFFECT
FDC to observer: SHOT

Rg Line Mixed
Corr Air



Comment: Observer spottings of range correct, mixed air, line, are considered adequate for the fire for effect and the observer ends the mission with END OF MISSION, MACHINEGUNS NEUTRALIZED.

★ Figure 14-3—Continued.

PART FOUR

FIRE DIRECTION

CHAPTER 15

FIRE DIRECTION, GENERAL

Section I. INTRODUCTION

15-1. Definitions

a. Fire Direction. Fire direction is the tactical employment of firepower, the exercise of tactical command of one or more units in the selection of targets, the concentration or distribution of fire, and the allocation of ammunition for each mission. Fire direction also includes the methods and techniques used in fire direction centers to convert calls for fire into appropriate fire commands.

b. Tactical Fire Direction. Tactical fire direction is the exercise of tactical command of one or more units in the selection of targets, the designation of units to fire, and the allocation of ammunition for each mission.

c. Technical Fire Direction. Technical fire direction is the conversion of calls for fire to appropriate firing data and fire commands.

d. Fire Direction Center. The fire direction center is the element of the artillery headquarters that consists of operations, intelligence, and communications personnel and equipment by means of which the commander directs artillery fire.

15-2. Scope

This manual is concerned primarily with technical fire direction for field artillery cannon battalions and batteries. For tactical fire direction, see FM 6-20-1 and FM 6-20-2.

15-3. Principles of Fire Direction

The methods employed in fire direction must insure—

a. Continuous, accurate, and timely fire support under all conditions of weather, visibility, and terrain.

b. Flexibility sufficient to engage all types of targets over a wide area.

c. Prompt massing of fires of all available units in any area within range.

d. Prompt distribution of fires simultaneously on numerous targets within range.

15-4. Command

a. Artillery headquarters control the fires of subordinate units. The headquarters may allocate reinforcing artillery fires in order to further the plan of the force commander. Division, group, corps, and army artillery headquarters are concerned primarily with tactical fire direction.

b. Fire direction as exercised by a cannon artillery battalion consists of tactical fire direction as well as technical fire direction.

c. When a battery is operating independently, fire direction is exercised by the battery commander through his executive officer and the fire direction personnel at the battery fire direction center.

Section II. FIRE DIRECTION CENTER

15-5. Role of the Fire Direction Center

The fire direction center (FDC) is that element of the gunnery team which receives the call for fire from the observer or higher headquarters, determines the firing data, and announces the fire commands to the firing battery. The fire direction center also determines and applies corrections to

standard firing table values in order to achieve the accuracy in firing that is characteristic of field artillery.

15-6. Principles of Operation

a. Production of Firing Data. Firing data normally are produced in the battalion fire direction

center. However, firing data may be produced in the battery—

- (1) When the battery is operating independently.
- (2) When more than two missions are being processed simultaneously and the S3 directs the battery to produce its own firing data.

b. Processing Fire Missions. Accuracy, flexibility, and speed in the execution of fire missions depend on—

- (1) Accurate and rapid preparation of firing data from the firing chart and transmission of commands to the firing batteries.
- (2) Accurate and rapid verification of firing data.
- (3) Efficient division of duties.
- (4) Adherence to a standard technique and procedure.
- (5) Efficient use of FDC plotting equipment and data determining devices.
- (6) Personnel functioning as a team and operating in a specified sequence.
- (7) Efficient use of communication equipment, including the use of a battalion fire direction center switchboard.

15-7. Fire Direction Center Personnel (Battalion)

The personnel that operate the fire direction

center are listed in *a* through *g* below. Detailed descriptions of their duties are given in chapter 18. All fire direction center personnel must be trained in communications and may be required to operate telephones and radio sets.

a. Battalion S3. The battalion S3 is the fire direction officer (FDO) of the battalion and is responsible for the functioning of the fire direction center. The assistant S3 must be capable of assuming the duties of the S3 whenever necessary.

b. Chief Fire Direction Computer. The chief fire direction computer is the senior enlisted member of the FDC and assists the S3 in the supervision of the fire direction center.

c. Horizontal Control Operator. The horizontal control operator (HCO) operates the horizontal control chart, normally a grid sheet, from which range and direction are determined.

d. Vertical Control Operator. The vertical control operator (VCO) operates the vertical control chart, normally a grid sheet supplemented by a 1:50,000 map, and determines site.

e. Computer. The computer (one per firing battery) converts chart data to firing data and announces fire commands to the firing battery.

f. Switchboard Operator. The switchboard operator installs and operates the FDC switchboard.

g. Radiotelephone Operator(s). The radiotelephone operator receives, records, and reads back calls for fire and subsequent corrections.

Section III. FIRING CHARTS

15-8. General

The firing chart is a photomap, a grid sheet, or a sheet of plain paper on which is shown the relative locations of batteries, registration points, targets, and other details needed in preparing firing data.

15-9. Map

A map is a graphic representation, drawn to scale, of a portion of the earth's surface as seen from above. Maps (normally 1:50,000) are used to supplement firing charts. A map is only as accurate as the ground survey from which it is made. Maps based on accurate ground survey require the least amount of additional survey for field artillery use. These maps provide direction and horizontal and vertical control and can be used as the basis

for field artillery survey. If the map is not based on accurate and adequate ground control, it should be used only to obtain approximate locations and vertical control to supplement a grid sheet firing chart.

15-10. Photomap

a. A photomap is a reproduction of an aerial photograph or a mosaic on which are added grid lines, marginal information, and place names. A photomap must not be considered exact until its accuracy has been verified. Errors caused by tilt, distortion due to relief, and errors due to poor assembly may be present in photomaps. If points cannot be located on the photomap by inspection, the scale must be determined before points can be located on the photomap by survey. Normally, vertical control can be established only by estimation.

Some photomaps have spot elevations, but interpolation is difficult and inaccurate.

b. Even though the photomap may be used initially, survey is started at once. This survey provides a check on the accuracy of the photomap. If the photomap proves to be inaccurate, a grid sheet firing chart based on survey is constructed.

15-11. Grid Sheet

A grid sheet is a plain sheet of paper on which are printed equally spaced horizontal and vertical lines called grid lines. Since the grid sheet bears no relation to the ground and basic information must come from other sources, any scale desired may be used. However, grid sheets used by the field artillery are printed to a scale of 1:25,000, with the distance between grid lines representing 1,000 meters. The location of all points placed on the grid sheet must be determined by either survey or firing. Horizontal and vertical control charts usually are grid sheets.

15-12. Purpose of Firing Chart

The firing chart is used to determine the range, direction, and vertical interval from the gun(s) to the target. The effectiveness of artillery fires depends, to a large degree, on the accuracy and completeness of the firing chart.

15-13. Types of Firing Charts

There are two types of firing charts used in an FDC—the surveyed firing chart and the observed firing chart.

a. The surveyed firing chart is a chart on which the locations of all key points (battery positions, registration points, OP's) are based either on survey (FM 6-2) or map inspection. All plotted points are in correct relation to one another and are tied together by actual map coordinates. When determination of actual map coordinates has not been completed, assumed coordinates may be used initially to tie together the points to be plotted. The procedures pertaining to construction of a surveyed firing chart and determination of data therefrom are covered in chapter 16.

b. The observed firing chart is a chart on which all chart locations must be established by firing. Relative locations of the batteries and targets can only be established by the adjustment of fire, hence the name "observed firing chart." Procedures pertaining to determination of data stated in chapter 16 apply to an observed firing chart. Details pertaining to construction of an observed firing chart are contained in chapter 26.

CHAPTER 16

CHART DATA

Section I. PLOTTING

16-1. General

Every effort must be made to insure the accuracy of data shown on the firing chart. All firing charts in the battalion should be identical to insure that any chart can be used to mass the fires of the battalion.

16-2. Plotting Equipment

The construction and use of a firing chart requires the use of special equipment. The accuracy obtained with this special equipment depends as much on plotting habits and care of equipment as on the accuracy of the equipment.

a. The 6H Pencil. Any line drawn on the firing chart from which measurements will be made must be drawn with a 6H (hard lead) pencil (①, fig. 16-1), sharpened to a wedge point. This procedure is required if the necessary accuracy is to be achieved.

b. The 4H Pencil. The 4H pencil (①, fig. 16-1) is used for lettering and to accentuate tick marks. It should be sharpened to a conical point.

c. Map Pins. Map pins (②, fig. 16-1), commonly referred to as plotting pins, are used to mark battery, radar, and OP positions and to plot all points on the firing chart.

d. Plotting Scale. The plotting scale (③, fig. 16-1), is used for measuring distances and for plotting and determining coordinates for critical points which must be located accurately, such as batteries, radar, OP's and registration points. The scale should always be used in plotting coordinates determined by survey computations. The scale is graduated in meters, yards, and inches. The meter and yard graduations are at scales of 1:25,000, 1:50,000, and

1:62,500. The plotting scale should never be used as a straightedge for drawing lines.

e. Coordinate Scale (Aluminum). The aluminum coordinate scale (④, fig. 16-1) is a square-shaped scale used for plotting and determining coordinates of targets other than registration points and coordinates determined by survey computations. This scale is graduated in meters and yards at scales of 1:25,000 and 1:50,000. The scale has a projecting knob for ease in handling.

f. Coordinate Scale (Plastic). The plastic coordinate scale (⑤, fig. 16-1) is a right-angled scale used for plotting and determining coordinates of targets other than registration points and coordinates determined by survey computations. This scale is graduated in meters and yards at scales of 1:25,000 and 1:50,000.

g. Protractor. The protractor (⑥, fig. 16-1) is a plastic angle-measuring instrument made in the shape of a half circle. The arc of the half circle is graduated in 10-mil increments with each 100-mil graduation numbered in a clockwise and a counterclockwise sequence. The hairline connecting the 0- and 3,200-mil graduations is used as a baseline for measuring angles. The straightedge of the protractor is graduated in yards—1:25,000 scale (black) and 1:50,000 scale (red).

h. Range-Deflection Protractor (Aluminum). The aluminum range-deflection protractor (RDP) (⑦, fig. 16-1) is used to measure angles and distances. It is used to measure range and deflection from the battery to the target and to polar plot. The left edge of the arm is graduated in meters (1:25,000 scale). The arc

of the range-deflection protractor covers 1,000 mils and is graduated in 5-mil increments with each 50-mil increment indicated by a long line.

i. *Military Slide Rule*. The military slide rule (MSR) (⑤, fig. 16-1) is discussed at paragraph 13-20d.

j. *Graphical Firing Table*. The graphical firing table (GFT) (⑥, fig. 16-1) is discussed at paragraph 17-8.

16-3. Tick Marks

a. A tick mark is a symbol used to mark the pinhole which represents the location of a installation or a target plotted on a firing chart. The tick mark (fig. 16-2) is constructed in the form of a cross starting approximately 40 meters from the pinhole on the chart and extending approximately 150 meters in length (1:25,000 scale). Normally, the lines of the tick mark are drawn parallel to the grid lines; however, if the plotted point falls on or very close to a grid line, the tick mark is drawn at a 45° angle to the grid lines. The tick mark for a surveyed point is drawn in black (4H pencil); the tick mark for a point located by firing (recorded targets) is drawn in red.

b. The identification of the point is placed in the upper right quadrant of the tick mark. The installation or activity is indicated in the following manner (fig. 16-2):

(1) *Battery*. The letter designation is shown in appropriate color; i.e., A—red, B—black, C—blue, D—orange.

(2) *Radar*. The military symbol is shown in green.

(3) *Forward observation post*. The military symbol and the call number of the observer are shown in black. (If the observer is from another unit, both the call sign and the call number will be used.)

(4) *Battalion observation post*. The assigned number shown in black; e.g., 02.

(5) *Registration points*. The registration point and the number assigned are shown in black; e.g., reg pt 3.

(6) *Targets*. The assigned target number is shown in black; e.g., AF 2415.

c. The altitude, in meters, of the plotted point is placed in the lower left quadrant in black.

d. If the plotted point has been fired on, the fuze used in fire for effect may be placed in the lower right quadrant.

e. If the target has been fired on with high-angle fire, the letters "HA" may be placed in the upper left quadrant.

f. The charge fired may also be placed in the upper left quadrant.

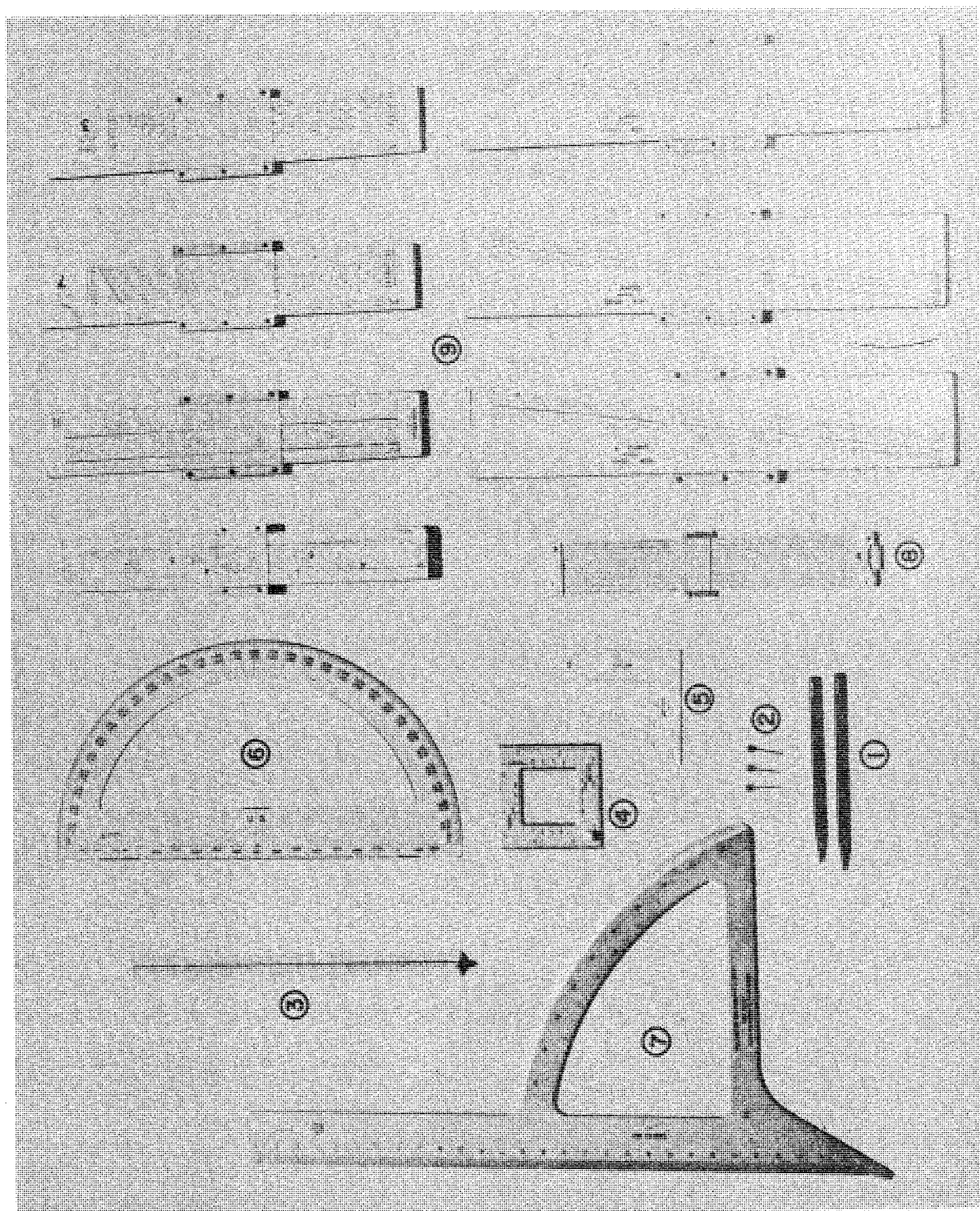
g. The pieces of an artillery battery are sometimes widely dispersed. Therefore, it may be necessary to plot the location of each piece or platoon center of each platoon.

16-4. Plotting a Point From Grid Coordinates With a Plotting Scale

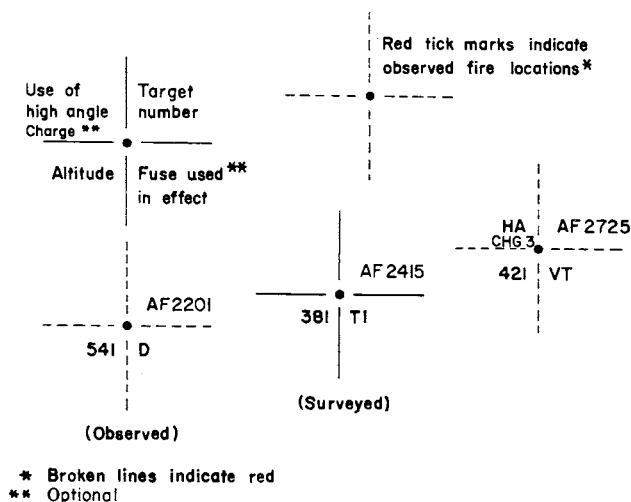
★a. A normal grid is defined as a grid that is printed to the exact scale of the plotting scale (fig. 16-3). To plot a point, the grid coordinates of which are 6241937749, on a normal grid, first locate grid square 6237. Then, using the grid square above 6237, place the 0 graduation of the plotting scale on the north-south line 62 and the 1000 meter graduation on the north-south line 63. Mark off 419 meters with a map pin. Move the scale one grid square below grid square 6237 and repeat the operation. Remove the pins and, using a 6H pencil, connect the two pinholes with a fine, light line. This will be the north-south line passing through the point. In a similar manner, determine the east-west line passing through the point. The intersection of these lines is the desired point, which is indicated by a tick mark made with a 4H pencil.

b. Grid lines are sometimes closer or farther apart than normal because of poor manufacturing processes or the shrinking or stretching of the grid paper. When grid lines are closer than normal, plot the point in the same manner as described in a above, inclining the scale so that the 0 of the scale is on one grid line and the 1,000-meter graduation is on the other grid line. The point will then be plotted in its true relation to the grid, as the 100-, 10-, and 1-meter digits express the proportional part of the distance between grid lines (fig. 16-4).

c. If the grid lines are farther apart than normal, measure the distance between the grid lines and find the difference from normal. The proportional part of this difference is added to



★Figure 16-1. FDC Equipment.



★*Figure 16–2. Marking plotted points.*

a measurement. For example, if the distance between grid lines is measured as 1,020 meters, the difference from normal is 20 meters. The proportional part of this distance for a 400-meter measurement is $400/1000 \times 20$, or 8 meters. The 400-meter measurement then is scaled as 408 meters (①, fig. 16-5).

d. Similar results can be obtained by diagonally inclining the plotting scale so that one 1,000-meter graduation is on one grid line and the other 1,000-meter graduation is on the adjacent grid line. The distance to be plotted is multiplied by 2, and that result is scaled. When the easting coordinate is plotted in ②, figure 16-5, the 400-meter measurement would be scaled as 800 on the inclined plotting scale.

16-5. Measuring Grid Coordinates of a Point With a Plotting Scale

Grid coordinates are measured in the same manner as they are plotted, and the distance is read directly between the point and the grid line. The first digit(s) of the easting grid coordinates is the number appearing at the top or bottom of the north-south line west of the point. The balance of the easting grid coordinate is the distance of the point east of this north-south line as measured with the scale. For the northing coordinate, the first digit(s) is obtained from the right or left of the east-west line south of the point and the balance of the northing grid coordinate is the distance of the point north of this line as measured with

the scale. If the grid lines are closer or farther apart than normal, measurements are made in the same manner as they are in plotting points.

16-6. Use of Coordinate Scale

When rapid massing on targets of opportunity or plotting of targets for an adjustment is necessary, plotting may be done with the coordinate scale (④ and ⑤, fig. 16-1). The use of the coordinate scale is described in FM 21-26.

16-7. Measuring and Plotting an Angle With a Protractor

Angles may be measured or plotted with the plastic protractor (⑥, fig. 16-1). FM 21-26 describes the use of a plastic protractor graduated in degrees.

16-8. Measuring and Plotting Distances With a Plotting Scale

The most accurate method of determining the distance between two points plotted on a firing chart is with the plotting scale. Care must be taken to use the correct scale on the plotting scale. After the direction of a line has been established on a chart, the length of this line may be plotted with the plotting scale.

16-9. Measuring and Plotting With a Range Deflection Protractor (Aluminum)

a. When several angles and distances are to be plotted or measured from one point and one reference direction (i.e., polar plotting from radar), the procedure is facilitated by the use of the range-deflection protractor.

b. The range-deflection protractor is prepared for polar plotting by numbering the 100-mil graduations on the arc in black as follows:

(1) The rightmost graduation is marked "0."

(2) Each succeeding 100-mil graduation is marked "1" through "9"; the leftmost graduation is unmarked.

c. Angles up to 1,000 mils can be measured conveniently with the range-deflection protractor. This measurement may be accomplished in the following manner:

(1) Place the vertex of the RDP at the point from which the measurement is to be made.

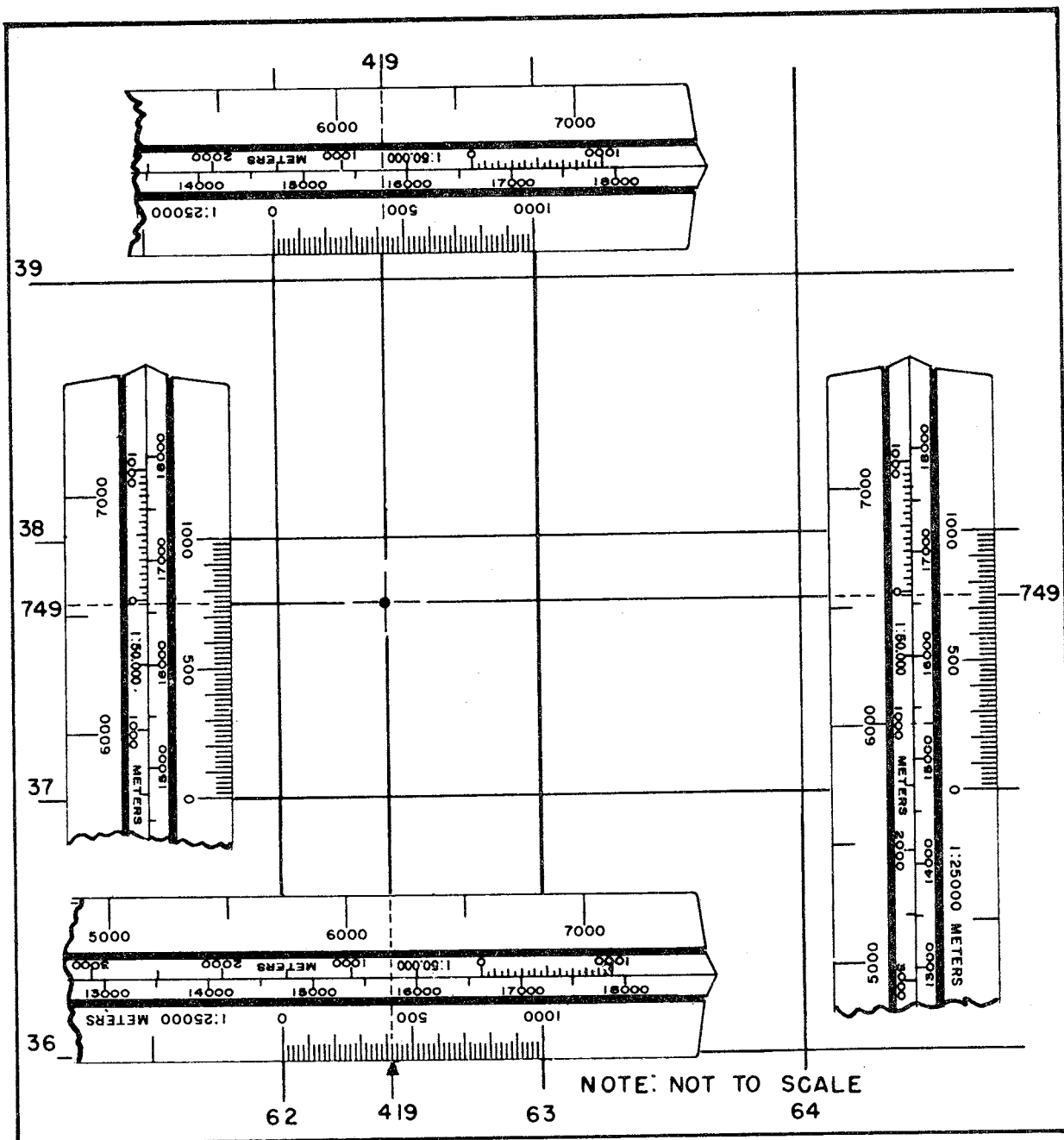


Figure 16-3. Plotting a point from coordinates on a normal grid

- (2) Place the left edge of the arm of the RDP so that it coincides with the line which is the left limit of the angle to be measured and then place a pin at the rightmost graduation on the arc of the range-deflection protractor.
- (3) Rotate the RDP until the left edge of the arm coincides with the line which is the

right limit of the angle and read the value of the angle from the azimuth scale opposite the pin placed along the arc.

d. To measure the distance in meters between two points, place the vertex of the RDP at one of the points and the left edge of the arm against the pin in the second point and read the distance opposite the pin in the second point.

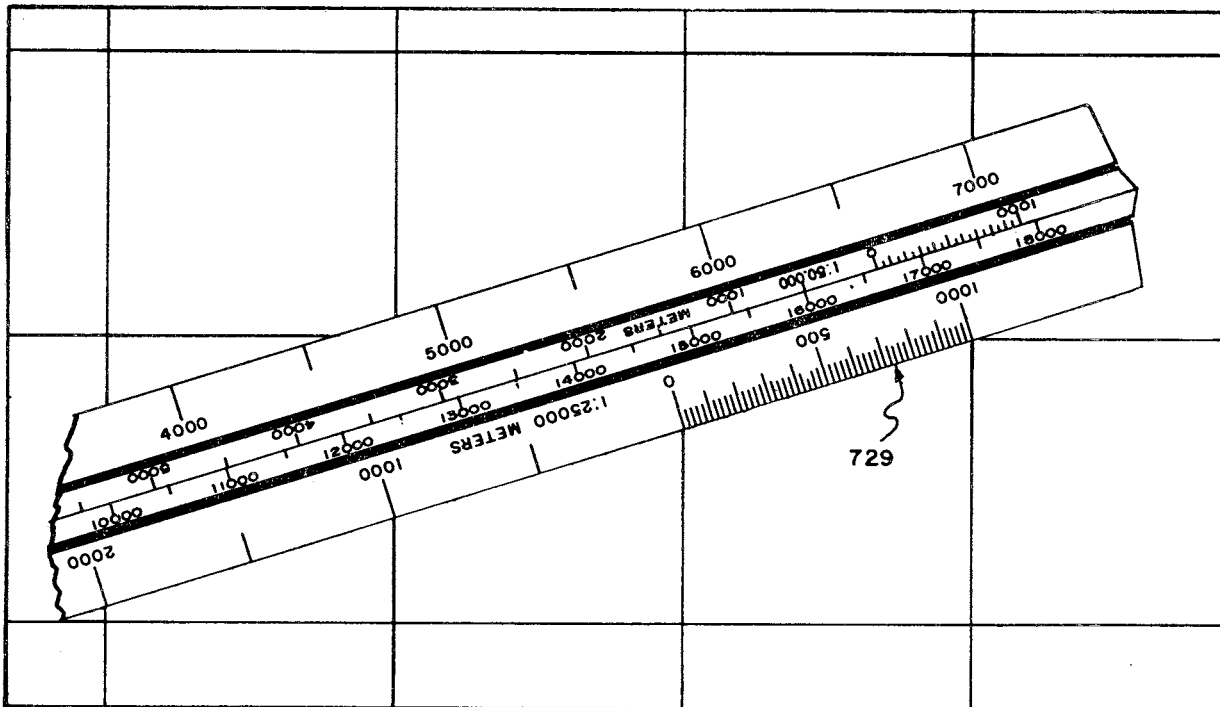


Figure 16-4. Plotting a point from coordinates when grid lines are closer than normal

e. The procedure for plotting an angle is as follows:

- (1) Place the vertex of the RDP at the point from which the angle is to be plotted.
- (2) Place the left edge of the arm so that it coincides with the line from which the angle is to be plotted.
- (3) Place the pin opposite the leftmost graduation on the arc if the angle is to the left or opposite the rightmost graduation if the angle is to the right.
- (4) Rotate the RDP through the desired angle, using the pin as an index.
- (5) Place a pin against the left edge of the arm.
- (6) Draw a line from the vertex of the angle through the pin location.

f. If a large number of angles are to be measured or plotted from a point, the chart should be indexed.

16-10. Preparing Chart With Polar Plot Indexes for a Range-Deflection Protractor

a. The point from which polar plotting is to be performed must be plotted on the firing chart.

b. Azimuth indexes are constructed on the firing chart at 1,000-mil intervals covering the target area (fig. 16-6). These indexes are constructed so that the left edge of the arm of the range-deflection protractor is aligned on an azimuth which is a multiple of 1000 when the appropriate index is opposite the rightmost graduation on the arc. The procedure for establishing the appropriate azimuth indexes is as follows:

- (1) Place the vertex of the RDP against a pin in the OP or radar position and the arm parallel to a convenient grid line. This establishes a reference line (not drawn) at an azimuth of 1,600, 3,200, 4,800 or 0 mils.
- (2) Place a pin opposite the azimuth corresponding to the last three digits of the direction in which the RDP is oriented. This value will be 600, 200, 800, 400, or 0, depending on the initial orientation of the range-deflection protractor. The location of the pin represents an azimuth index of 1,000, 3,000, 4,000, 6,000, or 0 mils, respectively. To locate azimuth indexes for 2,000 and 5,000, place a pin 1,000 mils right of the indexes for 1000 and 4000, respectively.

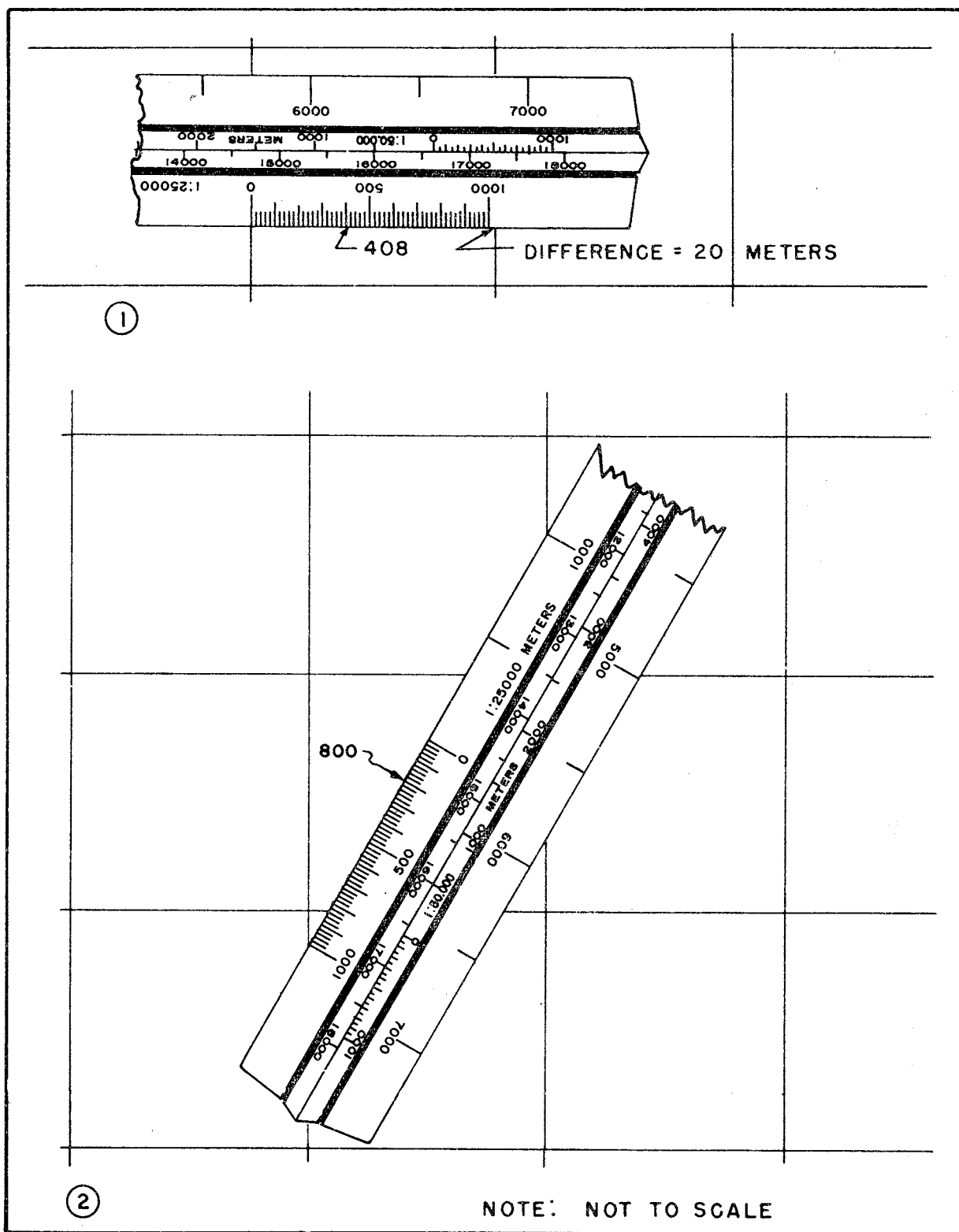


Figure 16-5. Plotting a point from coordinates when grid lines are more distant than normal (two techniques)

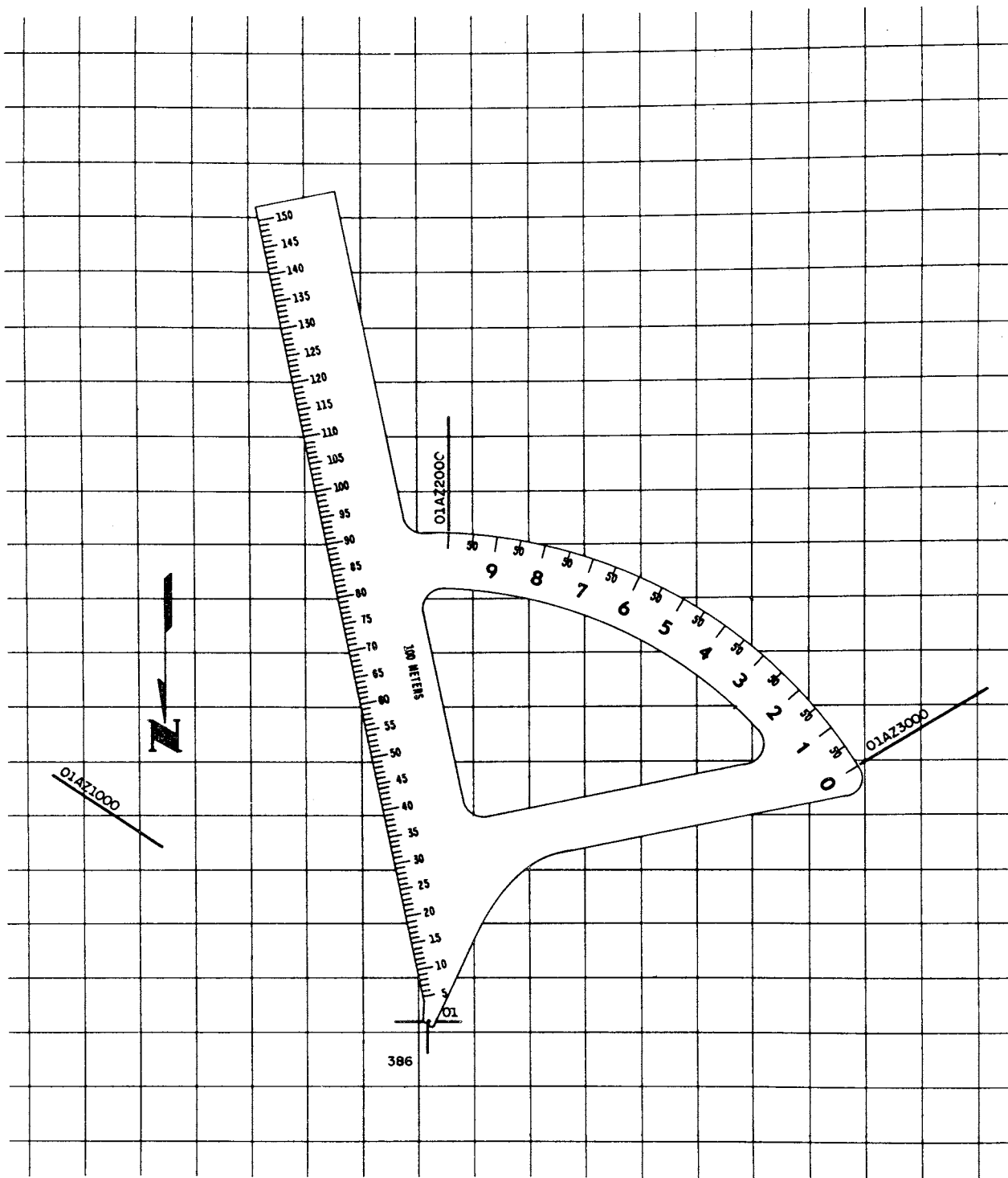


Figure 16-6. Range-deflection protractor and chart prepared for polar plotting

(3) Move the RDP so that the left edge of the arm is against the *pin*, remove the pin, and draw the azimuth index with a wedge-pointed 6H pencil. The index is a fine line approximately 2 inches long, extending 1 inch above and 1 inch below the pinhole. The index is labeled with the appropriate identification (01, 24, radar symbol, etc) and azimuth value along the left side of the line, beginning approximately one-eighth inch beyond the mil scale. For radar, the lettering on the indexes is green; for observation posts, the lettering is black.

(4) To establish an azimuth index 1,000 mils right (left) of a previously established index, place the leftmost (rightmost) graduation on the arc over the previously established index and then place a pin opposite the rightmost (leftmost) graduation. The index is then constructed at the pin location as in (3) above.

c. When the firing chart is indexed as in *b* above and the arc of the range-deflection protractor is marked as in paragraph 16-9b, the value of the azimuth measured or plotted is the sum of the azimuth marked on the azimuth index and the value read on the arc opposite that azimuth index.

16-11. Preparing Chart When Azimuth to a Known Point Has Been Reported From a Radar Measurement

There will be occasions when the azimuth to a point plotted on the firing chart can be measured by radar. In such cases the procedure shown below will be used to construct the azimuth index.

a. Place the vertex of the range-deflection protractor against the pin in the radar location and the left edge of the arm against a pin in the known point.

b. With the arc numbered as prescribed in paragraph 16-9b, place a pin opposite the graduation on the arc which is equal to the reported azimuth minus the next lower 1,000 mils; e.g., if the reported azimuth is 4350, place the pin opposite 350. The pin marks the location of the azimuth index for the next lower 1,000 mils; i.e., azimuth 4000.

16-12. Plotting a Point Located by Polar Coordinates

The procedure used to plot a point located by polar coordinates from an OP (or radar) is as follows:

a. Place the vertex of the range-deflection protractor against the pin in the OP location with the arc over the proper OP azimuth index. There will be only one OP azimuth index which can be used to polar plot a given point. The index to be used is the one numbered with the multiple of 1000 that is next lower than the azimuth reported by the observer.

b. Orient the range-deflection protractor so that the azimuth on the index used added to the value read from the arc opposite the index is equal to the azimuth reported. This causes the left edge of the arm to be on the azimuth reported from the observation post.

c. Place a pin along the left edge of the arm at the reported distance (in meters) from the observation post.

Example: It is desired to plot a target at an azimuth of 1,960 mils and a distance of 10,700 meters from 01. Place the vertex of the range-deflection protractor against the pin in 01. Rotate the protractor until 960 on the arc is directly over the index marked "01AZ1000." Without moving the protractor, place a pin along the left edge of the arm at 10,700 meters from 01. The pin marks the location of the target.

16-13. Rescinded

16-14. Target Grid

a. *General.* The target grid is a device for converting, by plotting, the observer's target locations and corrections with respect to the OT (observer-target) line to target locations and corrections with respect to the GT (gun-target) line. A target grid is operated in conjunction with each of the charts in the battalion. An arrow extends across the grid, with the point of the arrow at the zero mark of the azimuth circle, and indicates the direction of the OT line. The azimuth scale is printed around the edge of the grid. The scale is graduated in a counterclockwise direction at 10-mil inter-

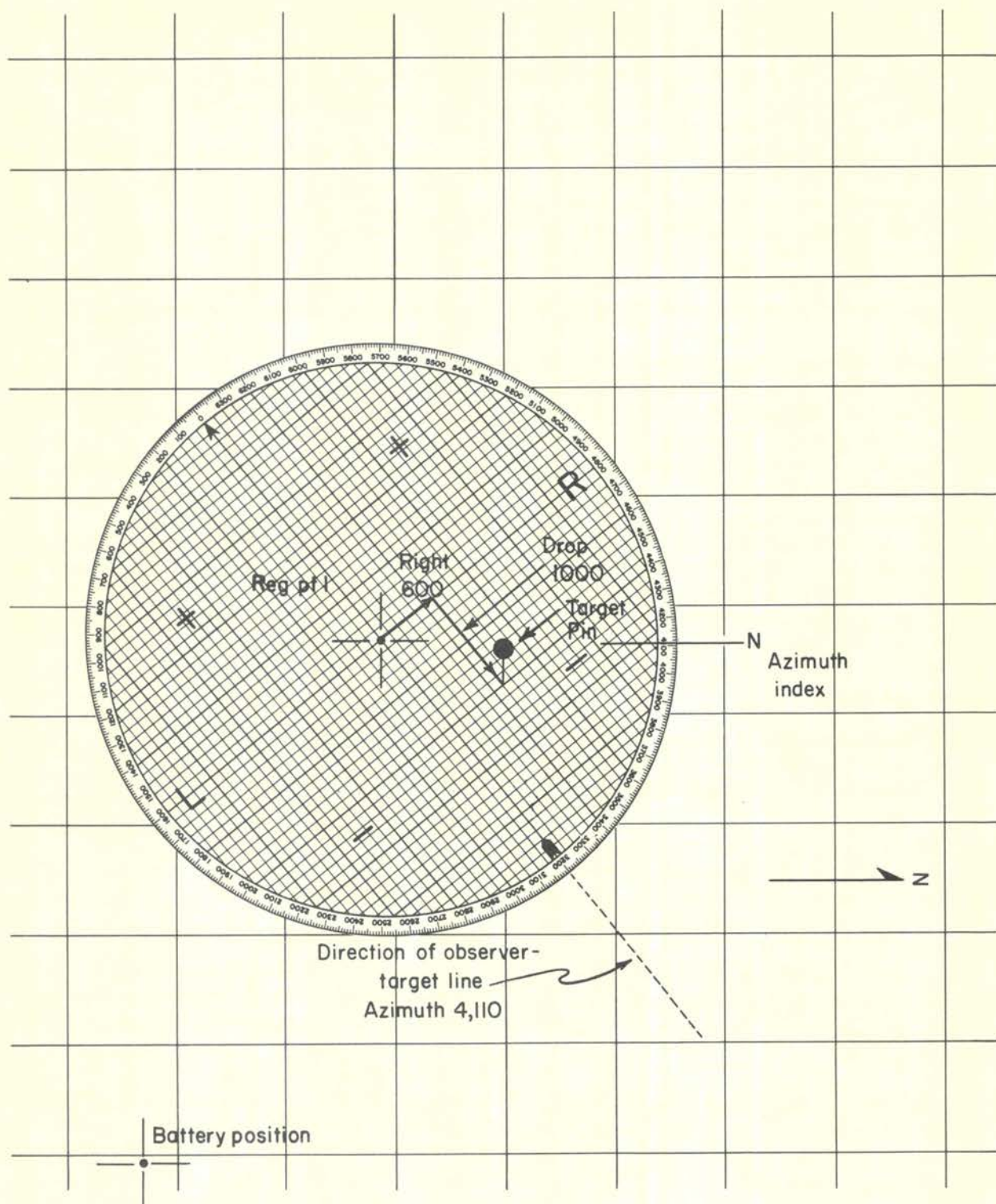


Figure 16-7. Plotting a target with the target grid by shift from a known point.

vals from 0 to 6,400 mils; each 100 mils is numbered. The azimuth scale is numbered in a counterclockwise direction because the grid is rotated and the index is stationary. The scale of the target grid must be the same as that of the firing chart. When the target grid is used with a firing chart with a scale of 1:25,000, the smallest graduation of the grid represents a distance of 100 meters (fig. 16-7).

b. Positioning the Target Grid. The center of the grid is placed over any point in the target area. This point may be the initial plotted location of the target to be adjusted on, a registration point, a meteorological checkpoint, a previously fired target, or an arbitrarily selected point, such as a grid intersection. The selection of a point other than the target to be plotted must be such that the target falls beneath the grid. If subsequent corrections cause the target to plot off the grid, the grid is moved to a suitable new position and reoriented on the same azimuth given in the call for fire.

c. Orienting the Target Grid. The chart operator constructs a north index on the chart at the edge of the target grid to indicate north or zero azimuth. The index is located by rotating the grid until the arrow (or a line on the target grid parallel to the arrow) is parallel to a north-south grid line and the arrowhead is pointing north. The index is drawn on the chart at zero azimuth; the index is drawn 1 inch above and 1 inch below the edge of the target grid and is marked "N" to prevent its being confused with other indexes on the chart. The target grid is oriented by rotating it

until the figure read opposite the north index is the same as the OT direction announced by the observer. This operation places the arrow and all lines parallel to it on the same direction as the OT line (fig. 16-7).

d. Plotting a Target by Shift From a Known Point. The target grid is placed so that both the known point and the target are beneath the grid and then is oriented on the direction given by the observer. The plotting pin is moved right or left of the known point along a line perpendicular to the arrow and forward or back along the lines parallel to it. Figure 16-7 shows the plot of an observer's call for fire; e.g., FROM REGISTRATION POINT 1, DIRECTION 4110, RIGHT 600, DROP 1000. In this manner the observer's target location is plotted in reference to a known point with respect to the OT line.

e. Measuring an Angle. The target grid may be used to measure an angle when a high degree of accuracy is not required. An angle is measured by placing the center of the target grid over the apex of the angle to be measured and the 0 of the azimuth circle over the right side of the angle. The size of the angle is read at the point on the azimuth circle that is intersected by the left side of the angle.

f. Marking the Target Grid. The target grid may be marked with a plus sign in the first and fourth quadrants, a minus sign in the second and third quadrants, an R to the right of the arrow near 4800, and an L to the left near 1600 (fig. 16-7) to aid the chart operator in plotting.

Section II. DETERMINATION OF CHART DATA

16-15. General

The purpose of a firing chart is to provide a graphic means for determining chart data. Chart data consist of the range (in meters), direction (deflection in mils), and vertical interval from the battery center to the target.

a. A horizontal control chart (usually a grid sheet) is used to determine the range and direction (deflection from the battery to the target). The range-deflection protractor is the device used to measure the range and deflection.

b. A vertical control chart (usually a grid sheet supplemented by a 1:50,000 map) is used to determine the vertical interval between the battery and the target. Range and direction may also be determined from the vertical control chart.

16-16. Numbering the Range Deflection Protractor for Deflection

Direction normally is measured and announced in terms of deflection. To facilitate the deter-

mination of deflection, number the mil scale on the arc of the range-deflection protractor as follows: Number the left graduation of the mil scale 0. Number the graduations in black to the right in 100-mil increments but omit the zeros representing hundreds; for example, write the numbers 100, 200, 300, etc, as 1, 2, 3, etc (fig. 16-8). Do not number the last graduation at the right end of the mil scale since the values cannot be read beyond the right end of the scale.

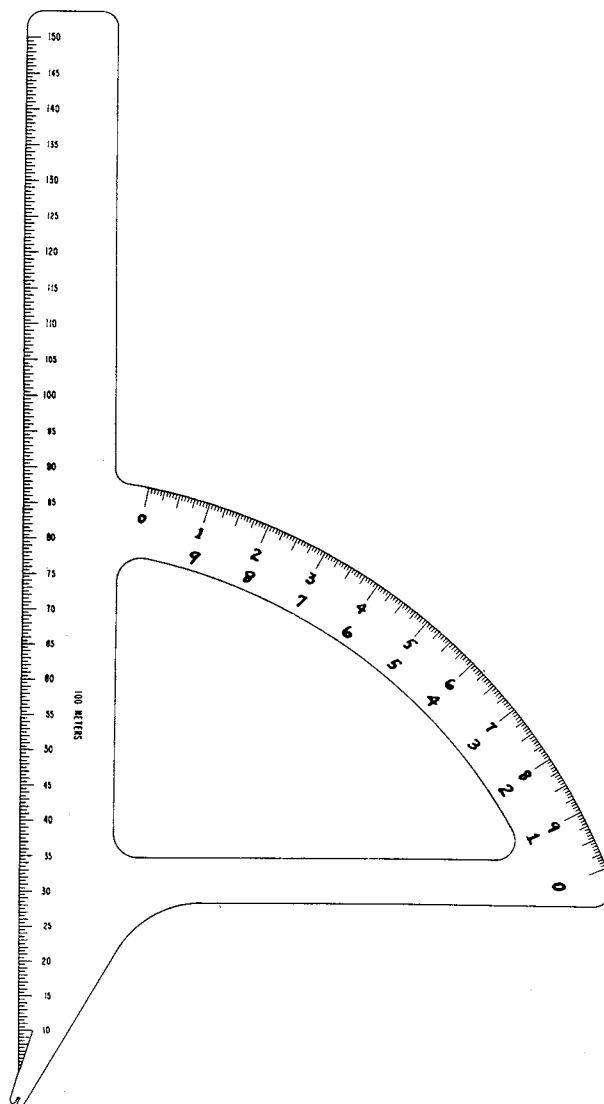
16-17. Preparing the Firing Chart

Before the firing chart can be used to determine chart data, the battery center must be plotted and deflection indexes constructed. When each piece or the platoon center is plotted on the firing chart, tick marks and deflection indexes are identified by using the standard battery color code together with the number of the piece or platoon.

a. Deflection Index. The deflection index is constructed and is used in conjunction with the range-deflection protractor to determine chart deflection (fig. 16-9). This index is constructed as follows:

(1) With the vertex of the range-deflection protractor against the pin in the battery position, the left edge of the arm is oriented in the direction in which the battery is laid. If the battery is laid on a grid azimuth, the azimuth is plotted from the battery position. Using the technique described in paragraph 16-9b (1) and (2), place a pin in the chart to represent the azimuth corresponding to the largest multiple of 1000 contained in the azimuth of fire. (Do not draw an index, since indexes are drawn only for OP's and radar positions.) Move the RDP until the last three digits of the azimuth of fire, as read from the azimuth scale of the RDP, are opposite the pin. The left edge of the RDP is now oriented on the direction in which the battery is laid. If the battery is laid on the registration point, the left edge of the RDP is placed against the pin in the registration point.

(2) Now place a pin in the chart at the 200-mil graduation. Move the RDP so that the left edge of the arm is against this pin, remove the pin, and draw a fine line (with a 6H pen-



★Figure 16-8. Range-deflection protractor numbered for measuring deflection and azimuths.

cil) on the chart along the range scale, extending it 1 inch above and 1 inch below the pinhole. Label this index with the appropriate battery designation and the number 3. The 3 represents 3,000 mils. (For referred deflections of 2400 and 2800 the pin would be placed at the 4 and 8 respectively, and the index would be labeled 2 for 2,000 mils).

(3) Draw an arrowhead on the index pointing toward the battery at a point one-eighth inch beyond the pinhole. Use the appropriate battery color to mark the arrowhead, battery designation, and number.

b. *Supplementary Deflection Indexes.* The right (left) supplementary index is located by placing the leftmost (rightmost) graduation on the arc of the range-deflection protractor over the deflection index and placing a pin opposite the rightmost (leftmost) graduation. The index is drawn as described in a (2) and (3) above. The left supplementary index will be labeled with the battery designation and the number 4, and the right supplementary index will be labeled with the battery designation and the number 2 for weapons with referred deflection of 3200.

16-18. Preparing the Firing Chart for 6,400-Mil Capability

When firing in a 6,400-mil sector is required and the batteries are plotted in the center of the firing chart, the indexes are constructed and numbered as shown in figures 16-10 and 16-11. Speed of adjustment is slowed somewhat by the large deflection shifts sometimes required in providing 6,400-mil coverage. This loss of time, caused by shifting trails, can be minimized by announcing a rough azimuth or a rough deflection immediately after the command BATTERY ADJUST. The methods of determining and directing this rough orientation are many and must be determined in view of the current situation and requirements. Some possibilities are discussed below:

a. *Rough Orientation by Azimuth.* Azimuth stakes would be placed out in the firing battery for the cardinal directions. The HCO would initially determine a rough azimuth by visual estimation or from a target grid placed face down over the battery position and oriented on grid north. The computer would then announce this azimuth in the special instructions. The howitzer crew, using the azimuth stakes, would immediately begin pointing the weapon in the appropriate direction.

★b. When indexing the firing chart for 6400 mil capability, it is not unusual to find that the RDP will measure a few mils more or less than 6400. When this is the case, the procedure is to apply a proportionate part of the error to each of the 1000 mil deflection indexes. This will place a small error in each deflection index rather than all the error at one point.

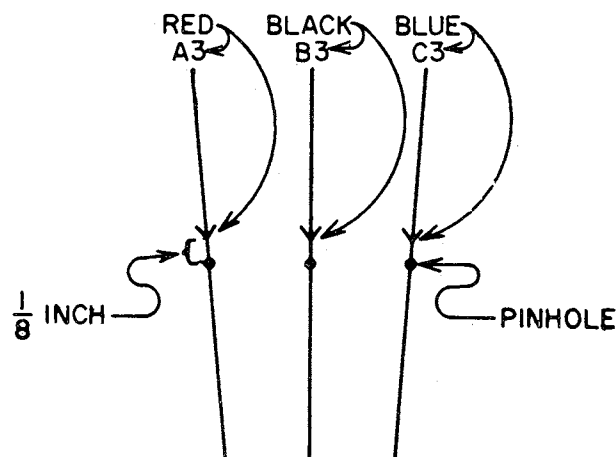


Figure 16-9. Deflection indexes.

16-19. Determination of Chart Range and Deflection

Chart range and deflection are measured as follows:

a. The vertex of the range-deflection protractor is placed against the pin in the battery position and the left edge of the arm is placed against the pin in the target location.

b. The range, in meters, is read on the scale of the arm opposite the pin in the target location. Range is measured and announced to the nearest 10 meters.

c. The chart deflection is read on the arc opposite the appropriate deflection index. The value of this deflection is determined by combining the reading on the arc at the deflection index with the 1000-mil designation of that index.

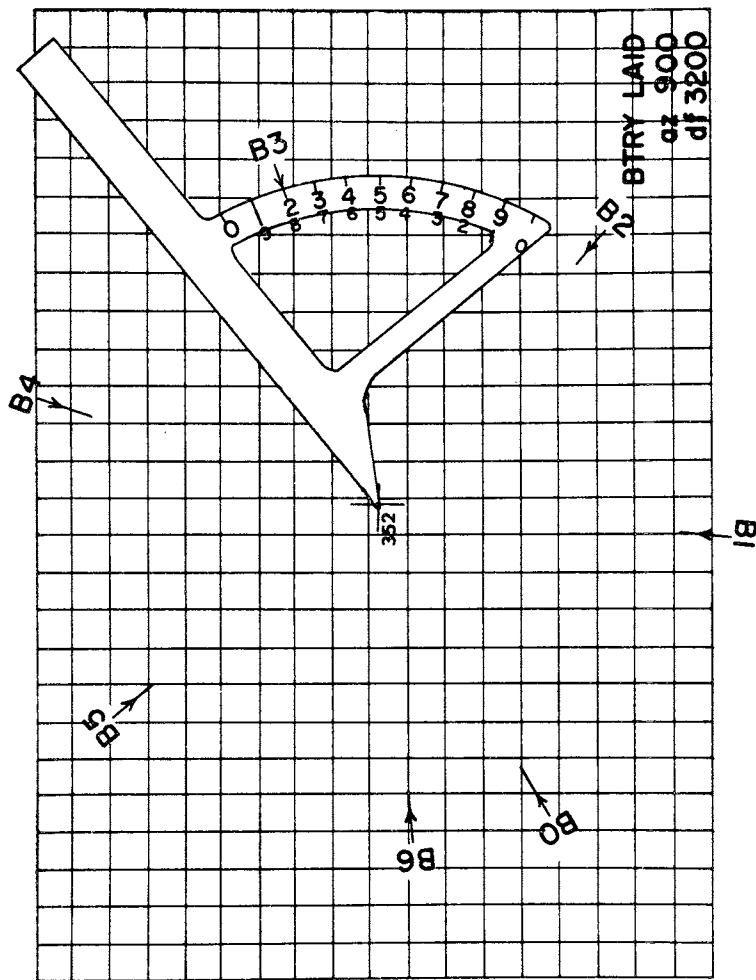
16-20. Target Altitude and Vertical Interval

a. The altitude of the target may be determined by one of the following four methods:

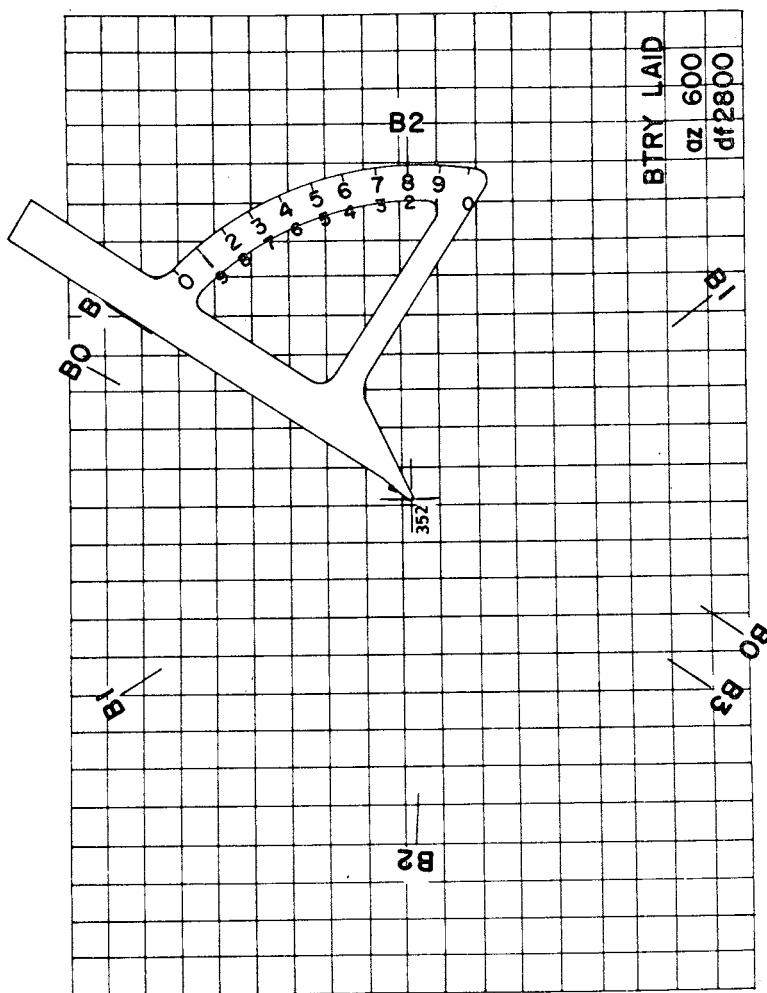
(1) The altitude may have been determined by survey.

(2) The call for fire may contain the altitude (usually the case when another unit or higher headquarters determines the target location).

(3) The call for fire may locate the target with reference to a known point. In this case, the vertical shift is applied to the altitude of



★ Figure 16-10. Firing chart for 6400 mil capability using the 0-6400 panoramic telescope.



★ Figure 16-11. Firing chart for 6400 mil capability using the 0-3200 panoramic telescope.

the known point to determine the altitude of the target. If no vertical shift is specified, the altitude of the target is assumed to be the same as the altitude of the known point. (The map altitude is disregarded.) The observation post is the known point in a polar plot mission.

(4) The altitude is determined from a map when the observer has located the target by grid coordinates.

b. The vertical interval is determined by subtracting the altitude of the battery from the altitude of the target. If the altitude of the target is greater than that of the battery, the sign of the vertical interval is plus. If the altitude of the target is less than that of the battery, the sign of the vertical interval is minus.

Chapter 17

Firing Data

17-1. General

The data determined from the firing chart (range, deflection, and vertical interval) must be converted to settings to be placed on the cannon and ammunition in order that the projectile may hit the point to which chart data have been measured. Firing data are charge, deflection, fuze setting, and quadrant elevation.

17-2. Charge

For cannons that fire semifixed or separate-loading ammunition, the amount of propellant may be varied. The propellant is packaged in increments, and the amount to be used is expressed in increments as, for example, CHARGE 5. Charge 5 is increments 1 through 5. The selection of charge is discussed in paragraph 18-15c(7).

17-3. Deflection

Firing deflection is the sum of the chart deflection (para 16-19) and the total deflection correction (para 20-11).

17-4. Elevation

★*a.* In order that an artillery piece, firing a given charge, may cause a projectile to achieve a prescribed range, the tube must be elevated from the horizontal to a vertical angle known as elevation. The elevation can be determined from the tabular or graphical firing table.

b. In the tabular firing tables, range is listed every 100 meters and an elevation, valid under certain assumed standard conditions, is given for each tabular range. Elevations corresponding to ranges between tabulated ranges are determined by interpolation.

c. On the GFT, elevation, valid under assumed standard conditions, is determined by placing the hairline of the cursor over the

range in question and reading the elevation under the hairline on the elevation scale.

17-5. Site

If the target (or desired point of burst) is at an altitude other than that of the artillery piece(s) to be fired, the trajectory may not pass through the target. This difference in altitude is compensated for by an additional element of firing data called site. The term "site" as used in artillery denotes the algebraic sum of the angle of site plus the complementary angle of site (*a* and *b* below). Site is the angle formed by the base of the trajectory and the line of site.

a. Angle of Site.

(1) Angles of site of 100 mils or less may be computed by using the simple mil relation, $\angle = W/R$ (para 8-3b), or the more accurate graphical site table (GST) (para 17-8b). When the mil relation is used, $\angle$ is the angle of site, *W* is the vertical interval, and *R* is the chart range in thousands to the nearest 100 (e.g., range 4060 is expressed as 4.1). Angle of site is computed to the nearest one-tenth mil.

(2) Angles of site greater than 100 mils must be computed by using the formula tangent of the angle of site equals the vertical interval divided by the chart range.

b. Complementary Angle of Site. The complementary angle of site (comp site) is computed by multiplying the angle of site by the complementary angle of site for a plus or minus 1-mil angle of site as appropriate (supplementary data, table G, of the tabular firing table). Comp site is computed to the nearest one-tenth mil.

c. Graphical Site Table. Site may be determined by using the GST (para 17-8b).

17-6. Fuze Setting

a. When time fuze is used, a fuze setting is made which will cause the fuze to function at the desired point on the trajectory. The fuze setting is a function of elevation plus complementary angle of site. When the complementary angle of site is small, the fuze setting may be considered a function of elevation alone.

★b. The fuze setting corresponding to the elevation (or elevation plus comp site) for fuze M564 may be determined from either the tabular or graphical firing table.

★c. For fuze M520, the fuze setting is obtained by adding the correction determined from the tabular firing table to the fuze setting for fuze M564.

d. The fuze setting is announced as TIME (so much).

17-7. Quadrant Elevation

Quadrant elevation is the sum of elevation and site and is announced in fire commands as QUADRANT (so much). Quadrant elevation may also be computed by adding angle of site to the elevation corresponding to range plus complementary range.

17-8. Graphical Tables

The basic source of ballistic data is the current tabular firing table for each cannon. The determination of firing data is simplified by the use of graphical tables. The most commonly used tables are the graphical firing table (GFT), and the graphical site table (GST).

★a. *Graphical Firing Table.* The graphical firing table is used principally for determining elevations for ranges determined from the firing chart. Each table consists of one or more rules and each rule consists of a base and a cursor. The construction of the rules varies depending whether they are for low angle or high angle fire.

(1) *Low angle GFT.*

(a) The base of the GFT is 18 inches long and $3\frac{1}{4}$ inches wide. A set of ballistic scales for a single charge is located on each side of the base. The ballistic scales are drawn at a slant to the base, angling from upper left to lower right. From top to bottom the scales are as follows:

1. *Deflection correction/drift scale.*

Projectile drift in mils, printed in black, appears on this scale. Drift is always to the right. Printed in red is the elevation at which drift changes. The deflection correction is written in pencil on this scale.

2. *100/R scale.* The 100/R scale gives the number of mils necessary to shift the point of burst laterally or vertically 100 meters for a given range. Numbers on the scale are printed in red.

3. *Range scale.* The range scale is the basic scale and all other scales are plotted with reference to it. Range is expressed logarithmically in meters and varies for each charge. The range scale is developed to give as large a range spread as possible and still permit graduations large enough for accurate readings. Range is read to the nearest 10 meters.

4. *Elevation scale.* The elevation scale is graduated in mils to show elevation; elevation increases from left to right and is read to the nearest 1 mil. Numbers on this scale are printed in black and red. The red numbers (on the charge 5 scale, those elevations between 200 and 500 mils) denote the elevations which are within range transfer limits for the one plot GFT setting. For the one plot GFT setting, the range to the registration or met check point must be between the leftmost and rightmost red elevation numbers.

5. *Fuze setting scale.* The fuze setting scale gives the fuze setting for the M564 fuze and is read to the nearest 0.1 increment.

6. *Fork scale.* The fork scale is graduated in mils to show the change in elevation necessary to move the mean point of impact four range probable errors. Numbers on this scale are printed in red.

7. *Change to fuze setting for a 10-meter changed in height of burst scale.* This scale is graduated in 0.01 increments and is read to the nearest 0.01 increment. It indicates the amount of correction which must be applied to the M564 fuze setting to raise or lower the height of burst 10 meters at a given range.

8. *Met check gagepoints.* Above the fuze setting line are red triangular gagepoints. The apex of each triangle points to the quadrant elevation which, under standard condi-

tions, results in the maximum ordinate of the trajectory passing through a whole line number of a met message. The ranges and quadrant elevations at the met check gagepoints are preferred for met plus VE computations.

9. *Height of burst probable error gagepoints.* Above the fork scale on all GFT's (except that for charge 1) are two red triangular gagepoints. The gagepoint on the right indicates the range and fuze setting at which the probable error in height of burst is 15 meters. Larger height of burst dispersion must be expected when time fuze is used with a particular charge at ranges exceeding that indicated by the right gagepoint. The triangular gagepoint on the left indicates the range at which the probable error in height of burst for the next lower charge is 15 meters.

10. *Range probable error gagepoint.* Above the change in fuze setting for a 10 meter change in height of burst scale is a black triangular gagepoint which indicates the range and elevation at which the range probable error is 25 meters. Where there is no triangle shown, the range probable error does not reach 25 meters for the charge.

11. *Range K line.* The range K line is a broken black line near the right edge of the rule. The angle the range K line makes with the scales geometrically portrays the predicted rate at which the range K varies with range. An elevation gagepoint drawn parallel to the range K line provides elevations which vary at the same predicted rate as does range K.

12. *Fuze K line.* The fuze K line is a broken black line near the left edge of the rule. The angle the fuze K line makes with the scales geometrically portrays the predicted rate at which the fuze K varies with range. A time gagepoint drawn parallel to the fuze K line provides fuze settings which vary at the same predicted rate as does fuze K.

(b) The procedure for determining the elevation and fuze setting with the graphical firing table when no corrections are known is as follows:

1. Place the hairline over the measured chart range.

2. Read the elevation under the hairline from the elevation scale.

3. Read the fuze setting under the hairline from the fuze setting scale.

(2) *High-angle GFT.*

(a) High-angle scales are developed with several charges on each side of the base and are arranged so that the charges are overlapping and data may be read from one side with the rule held in the same position. From top to bottom the scales are as follows:

1. *100/R scale.* The scale is identical with the low-angle 100/R scale.

2. *Range scale.* The range scale is graduated in meters to show range logarithmically. One range scale suffices for all charges appearing on one side of the base.

3. *Elevation scale.* The elevation scale is graduated in mils to show elevation; elevation increases from right to left and is read to the nearest 1 mil.

4. *10-mil site scale.* The 10-mil site scale gives site for each 10-mil angle of site at the elevation and charge selected. Numbers on this scale are printed in red. The sign of the site is opposite that of the angle of site.

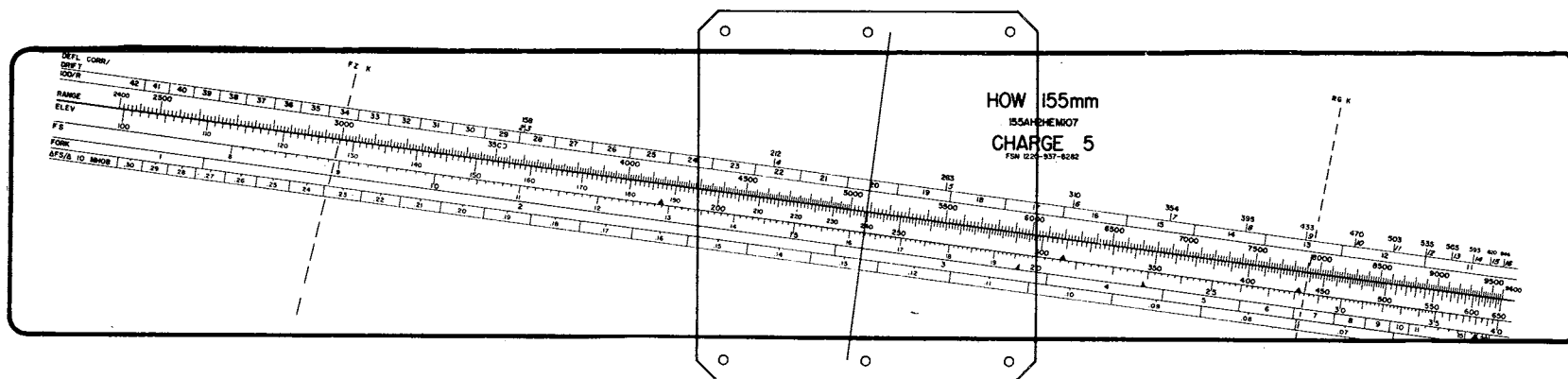
5. *Drift scale.* The drift scale is graduated in mils to show projectile drift. Drift is always to the right.

6. *Time of flight scale.* The time of flight scale is graduated in seconds to show projectile time of flight. Fuze settings are not given because time fire is not employed for high angle fire due to the large height-of-burst probable error encountered with mechanical time fuzes.

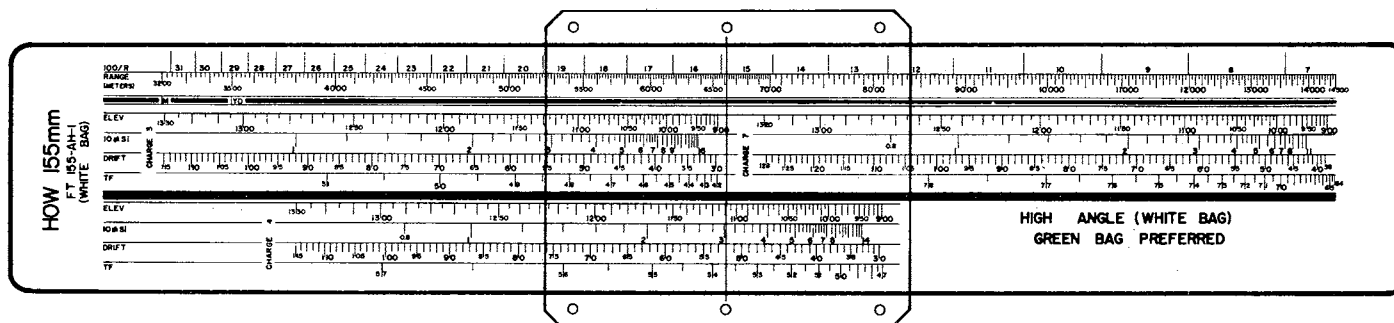
(b) Corrections determined from registration are applied as described in chapter 25.

b. *Graphical Site Table.*

(1) The determination of site by use of angle of site and the complementary angle of site factor from the firing tables is time consuming. The graphical site table (GST) can be used to facilitate the computation of the angle of site (vertical angle) or site. The GST can also be used to determine vertical interval when site or angle of site (vertical angle) and range (distance) are known. The GST consists of the base, which contains the D scale (site



★Figure 17-1. Low angle graphical firing table.



★Figure 17-2. High angle graphical firing table.

and vertical interval); a slide, which contains the C scale (range) which can be read in yards or meters, site-range scales for various charges in meters, and yard and meter gagepoints; and the cursor, which is a clear piece of plastic with a vertical hairline through the center. The C and D scales are identical with those on any slide rule and are used on the GST for determining angles of site of 100 mils or less or vertical interval when angle of site is known. (For angles of site greater than 100 mils, the military slide rule and the tangent function are used.) There are two site-range scales for each charge—one in red, marked "TBG" (target below gun), and the other in black, marked "TAG" (target above gun). The scales are so constructed and placed with respect to the C scale that when vertical interval (D scale) is divided by range on the site-range scale, complementary angle of site is included in the result (site). The TAG and TBG site-range scales differ by small amounts because the complementary angle of site factor for a minus angle of site differs from the factor for a plus angle of site. These scales are used in computing site or determining vertical interval when site is known. The meter (M) (when the verti-

cal interval is in meters) or the yard (YD) (when the vertical interval is in yards) gagepoint, rather than the normal index, is used for multiplication or division of the result by 1.0186 and, in effect expresses the formula $\text{m} = 1.0186W/R$, which is more precise than the mil relation formula $\text{m} = W/R$. When the GST is used in solving problems, range is always used to the nearest 10. (See the back of the GST for instructions on its use.) All newer GST models have a complete FDC spotting table beneath the slide except for the observer spotting column which is on both sides and at each end of the slide.

(2) The graphical site table (GST) has, at the left and right ends of the C (range) scale, yard and meter gagepoints labeled in red "YD" and "M", respectively. The gagepoints may be used to convert yards to meters by following the procedure in (a) and (b) below. If it is desired to convert meters to yards, the procedure is reversed.

(a) Place the M gagepoint opposite the range in yards on the D (site and vertical interval) scale.

(b) Opposite the YD gagepoint, read the range in meters.

CHAPTER 18

FIRE DIRECTION PROCEDURES

Section I. INTRODUCTION

18-1. General

The fire direction procedures presented herein are for battalion fire direction. The personnel of the fire direction center (FDC) are assigned specific duties. Those duties are performed in a prescribed sequence and manner to provide efficient fire control.

18-2. Battalion S2

The battalion S2 is the intelligence officer. FM

6-20-2 contains detailed discussions of his duties. Duties of the S2 which pertain to fire direction are to—

- a. Locate, report, and recommend likely targets to the S3.
- b. Advise the S3 on methods of attacking targets.
- c. Obtain and distribute maps and serial photographs and assist in target restitution.

Section II. DUTIES OF BATTALION FDC PERSONNEL, GENERAL

18-3. Organization

The battalion FDC team is composed of the S3, the assistant S3, one chief fire direction computer, one assistant chief fire direction computer, one horizontal control operator, one vertical control operator, one computer for each battery organic or attached to the battalion, and the number of radiotelephone operators necessary to monitor and operate the radio and wire communication nets of the battalion. In addition to these members of the battalion FDC team, a switchboard operator is needed to install and operate the battalion FDC switchboard.

18-4. Battalion S3 (Assistant S3)

The battalion S3 is the operations and training officer. FM 6-20-2 contains a detailed discussion of his duties. The battalion S3 is also the gunnery officer of the battalion. The S3 plans, coordinates, and supervises the activities of the battalion and battery fire direction centers and is responsible for the training of the fire direction personnel. The assistant S3 must be able to perform the duties of the S3. The duties of the S3, when engaged in fire direction are to—

- a. Actively supervise the battalion fire direction center.
- b. Supervise the functioning of the battalion fire direction wire and radio nets.
- c. Inspect the plot of each reported target, de-

cide how to attack the target, and issue the fire order.

d. Direct and supervise the computation and transmission of corrections, such as registration, met, and velocity error (VE).

e. Insure that appropriate fire direction records are maintained.

f. Supervise the preparation and execution of prearranged fires.

18-5. Chief Fire Direction Computer (Assistant Chief Fire Direction Computer)

The chief fire direction computer is the senior enlisted member of the battalion fire direction center. He must be capable of operating and supervising the operation of the communication facilities within the fire direction center. He must be thoroughly proficient in both communication and gunnery procedures. His specific duties are to—

- a. Supervise all enlisted members of the fire direction center.
- b. Compute registration, met, and velocity error corrections.
- c. Inform the S2 as to the status and progress of fire missions.
- d. Maintain the necessary FDC records.

18-6. Horizontal Control Operator

The duties of the horizontal control operator (HCO) are to—

- a. Prepare and maintain the horizontal control chart (grid sheet).
- b. Plot target locations.
- c. Determine and announce range and deflection.
- d. Determine the size of the angle T and announce it when necessary.
- e. Assist the vertical control operator and the computer in determining replot data.
- f. Replot targets.
- g. Operate gun direction computer, M18 (FADAC).

18-7. Vertical Control Operator

The specific duties of the vertical control operator (VCO) are to—

- a. Prepare and maintain the vertical control chart.
- b. Maintain overlays to include situation, fire capability, and dead space.
- c. Inform the S3 when calls for fire plot close to friendly locations or patrols or within no-fire lines.
- d. Plot targets and determine and record their altitudes and announce the altitudes when required.
- e. Compute the site for each battery and announce that site to the appropriate computer when requested.
- f. Assist the S3 in selecting the basis for corrections or in selecting the charge and lot when the basis for corrections is not to be announced.
- g. Assist the computer and the horizontal control operator in determining replot data.
- h. Act as a horizontal control operator in the event of multiple missions.
- i. Assist the chief fire direction computer as directed.
- j. Provides a check for the horizontal control operator as time permits.

18-8. Computer

The duties of the computer are to—

- a. Record calls for fire, fire orders, firing data, corrections, and all other data which the S3 directs and maintain the necessary records.
- b. Compute and transmit deflection (i.e., chart deflection plus deflection correction) to the firing battery.
- c. Determines the elevation and the fuze setting.

d. Combine the announced site with 20/R (height of burst over range) when required and compute changes in site during the adjustment.

e. Combine the site with the elevation to determine quadrant elevation.

f. Transmit fire commands to the firing battery in the proper sequence.

g. Announce, when acting as adjusting battery computer, corrections to fuze and height of burst to the nonadjusting battery computers.

h. Compute met, VE, and special corrections and deflection differences when directed.

i. Assist in the conduct of registrations and the determination of registration corrections.

j. Determine data for replot with the assistance of the vertical control operator and the horizontal control operator.

k. Transmit current chart data and corrections to the battery fire direction center.

l. Construct the deflection correction scale.

m. Record the battery executive officer's report.

n. Prepare data sheets and maintain the record of all data sheets for prearranged fires sent to the firing battery.

18-9. Switchboard Operator

The switchboard operator must be trained in FDC communication procedures. His specific duties are to—

- a. Install and operate the FDC switchboard.
- b. Assist in the installation of radio/wire integration and local FDC circuits.
- c. Prepare and maintain a traffic diagram.
- d. Perform the necessary communication checks to insure that the FDC circuits operate properly.

18-10. Radiotelephone Operator(s)

The radiotelephone operator(s) must be trained in FDC communication procedures. His specific duties are to—

- a. Operate a telephone or radio in the fire direction center.
- b. Install remote control or radio/wire integration circuits from the radio vehicle to the fire direction center.
- c. Repeat calls for fire received by telephone or radio.
- d. Make communication checks as directed.

Section III. SPECIFIC FDC PROCEDURES

18-11. Charts

a. *S3 Chart.* If the S3 desires, a separate chart is constructed to show the fire capabilities and the locations of firing batteries, forward troop locations, no-fire line, registration points, and met checkpoints. This chart should be a map.

b. *Horizontal Control Chart.* The horizontal control chart is usually a grid sheet on which are plotted the locations of the firing batteries, surveyed observation posts, field artillery radars, registration points, met checkpoints, final protective fires, and targets as ordered by the S3 or requested by the observers. The horizontal control operator (HCO) maintains the horizontal control chart.

c. *Vertical Control Chart.* The vertical control chart is normally a grid sheet supplemented by a 1:50,000 map on which are plotted the locations of the firing batteries, surveyed observation posts, registration points, met checkpoints, final protective fires, and targets as ordered by the S3 or requested by the observers. The vertical control chart may be used during multiple missions to produce horizontal data. The vertical control operator (VCO) maintains the vertical control chart, and the 1:50,000 map on which are plotted firing battery locations and deflection indexes. He maintains the following overlays for use with the map:

- (1) A fire capabilities overlay.
- (2) A dead space overlay.

(3) A situation overlay on which are posted the no-fire line, friendly locations, routes of current and planned patrols, registration points, and recorded targets.

d. *Report of Surveyed Data.* A sheet of paper on which are tabulated the grid coordinates and altitude of each firing battery and all critical points plotted on the chart should be attached to each chart for convenience. In addition, the azimuths on which the batteries are laid, the azimuth of the orienting lines, the orienting angles, and the reference direction for the surveyed observation posts should be recorded.

18-12. Equipment

a. *Vertical Control Operator and Horizontal Control Operation.* Each chart operator will have, in addition to the more common equipment, such as plotting pins, colored pencils, etc., a coordinate scale and a range-deflection protractor. In addition to the items mentioned, the vertical control operator will have a GST for each caliber weapon for which he must compute site.

b. *Computer.* Each computer will have a GFT and TFT for the caliber and type of weapon for which he is computing.

18-13. Recording the Call for Fire

a. Most calls for fire will reach the FDC from an observer. Missions coming to the battalion FDC by wire or radio are received and read back by a radiotelephone operation or by the computer. The radiotelephone operator insures that all members of the FDC are alerted to the mission by announcing FIRE MISSION.

★b. All computers not actively engaged in another mission record the call for fire on DA Form 3622 (FDC Computer's Record).

18-14. Plotting the Target Location

When a call for fire is received, each chart operator, not engaged in another fire mission, immediately plots the location of the new target.

18-15. Fire Order

a. When a target is plotted, the S3 examines its location relative to the friendly forces, no-fire line, zones of fire, and registration points. From this examination and considering the factors listed in chapter 27, he decides how to attach the target, unless for some reason the mission should not be fired.

b. The S3 issues a fire order which consists of some or all of the elements listed below. The sequence indicated in (1) through (12) below is followed to avoid errors and confusion and to save time. Inapplicable elements are omitted. The timely delivery of fire should not be delayed to complete the fire order.

c. The following considerations affect the elements of the fire order:

<i>Element</i>	<i>When announced</i>	<i>Example</i>
(1) Battery(ies) to fire	Always	BATTALION.
(2) Adjusting battery	When applicable	BRAVO.
(3) Method of fire of adjusting battery.	When different from observer's request.	CENTER LEFT.
(4) Basis for correction	When applicable	USE GFT.
(5) Distribution	When applicable	SHEAF, 50 METERS.
(6) Projectile	When different from observer's request.	SHELL WP.
(7) Ammunition lot and charge.	When applicable	LOT TZ, CHARGE 5.
(8) Fuze	When different from observer's request.	FUZE TIME IN EFFECT.
(9) Number of rounds	Always in area fire; never in precision fire.	5 ROUNDS.
(10) Range spread, lateral spread, or zone.	When different from observer's request.	RANGE SPREAD.
(11) Time of opening fire	When different from observer's request.	AT MY COMMAND.
(12) Target number	Always	TARGET ALFA FOXTROT 2413.

(1) *Batteries to fire.* The decision as to which battery or batteries will fire for effect in a mission depends on—

- (a) The number of batteries available.
- (b) The size of the area to be covered and the accuracy of location.
- (c) The caliber, type, and number of weapons per battery.
- (d) Whether or not surprise fire is possible.
- (e) The importance of the target.
- (f) The relative locations of batteries to each other and to the target.
- (g) Whether the purpose of fire is neutralization, harassment or interdiction.
- (h) The battery with the most recent or best corrections in the zone to be covered.
- (i) The status of ammunition.
- (j) The policies of the commander.

(2) *Adjusting battery.* For registration and for missions requiring fires of the battalion, it is usually better to use the midrange battery as the adjusting battery. If a battalion consists of different caliber weapons, the battery with the smallest caliber weapons is normally chosen as the adjusting battery.

(3) *Method of fire of adjusting battery.* Unless the observer requests a different method of fire, volley fire by the center platoon is used during the adjustment.

(4) *Basis for corrections.* As FADAC is the primary means of determining firing data, the

basis for corrections need not be included in the fire order except when firing data is to be determined graphically. When this is the case the S3 will announce USE GFT in the basis for corrections.

(5) *Distribution.* When the S3 desires or the observer has requested a pattern of bursts other than that obtained by firing a parallel sheaf, the fire order must include a command for distribution. In those rare cases when special corrections are desired, the S2 commands SPECIAL CORRECTIONS followed by a description of the sheaf desired; e.g., SPECIAL CORRECTIONS, CONVERGED SHEAF. When the S3 wishes to adjust only the width of the sheaf by the rapid computation and application of a deflection difference, he indicates that wish by including in the fire order a command indicating the desired width of sheaf; e.g., SHEAF 100 METERS.

(6) *Projectile.* The projectile or combination of projectiles selected depends on the mission and the nature of the target. If neither the observer's call for fire nor the fire order specify the projectile to be fired, shell HE is used.

(7) *Ammunition lot and charge.*

(a) There can be an appreciable difference in the ballistic characteristics of different propellant lots of ammunition. Disregard of propellant lot numbers can seriously impair the accuracy of fire. Mixing propellant lots in a single observed fire mission can materially increase the

dispersion pattern and can even invalidate an adjustment. Large propellant lots normally are reserved for registrations and subsequent transfers (observed and unobserved). Small propellant lots are expended on battery missions when adjustment is necessary. Accurate ammunition records, to include a record of lot numbers, must be maintained at section, battery, and battalion levels.

(b) For fixed and semifixed ammunition, the ammunition lot number pertains to an assembled projectile-propellant combination. For simplicity, the lot numbers may be coded; e.g., lot X. Letters at the beginning of the alphabet should not be used to designate lots. This will prevent confusion in the fire order. For separate-loading ammunition, when a specific projectile-propellant combination is desired, the lot may be coded as lot XY, with X designating projectile lot and Y designating propellant lot. Segregation and coding of fuzes by lot number is necessary for time fuzes only.

(c) The mission, nature of the target and terrain, ammunition available, type of fuze to be used, range, and effects sought govern the selection of the charge to be used.

(d) Each computer will have readily available a list of GFT settings showing the lot numbers and charges used. If FADAC is to be used to determine the firing data, only the lot number should be specified in the fire order. When FADAC is not available, or if for any other reason the S3 decides to use the GFT, the lot number and charge will be specified to insure that the computer will select the most current corrections.

(e) When a mission requiring adjustment is to be fired by only one battery, the lot number specified should be one that implements the battery commander's plans and policies with respect to expenditure of lots on hand; e.g., consume the smallest of the odd lots first.

(f) A battalion may be composed of different caliber batteries. The lot number and the charge, if announced, would be announced for each battery in this case. For example, BATTALION, ALFA: ALFA, LOT XRAY, CHARGE 5; BRAVO, LOT XRAY YANKEE, CHARGE 4; etc.

(8) *Fuze*. The mission, description of target and terrain, fuzes available, range, and effects sought govern the selection of the fuze to be used.

The omission of fuze in the fire order indicates agreement with the observer's selection of fuze.

(9) *Number of Rounds*. The mission, description of target, batteries and ammunition available, and pertinent orders from higher headquarters, govern the number of rounds to be fired in fire for effect. Each cannon within the element *Battery(ies) to fire (b)(1) above* will fire the number of rounds specified.

(10) *Range spread, lateral spread, or zone*. The area to be covered, the accuracy of the target location, and the probable error of the weapon should be considered in determining the range spread, lateral spread, or zone to be used. Normally, a battalion should not fire with a range spread greater than 1 C (100 meters) between batteries, because a greater spread will not give uniform coverage of the target area. When a zone is to be fired, the fire order should specify the zone in terms of mils and quadrants; e.g., ZONE 5 MILS 5 QUADRANTS. If the number of quadrants to be fired is three, it need not be stated.

(11) *Time of opening fire*. The mission description of the target, and the effect desired govern the selection of time of opening fire, such as TIME ON TARGET (TOT), AT MY COMMAND, or any specific time according to a prearranged schedule. The omission of a time for opening fire indicates that the batteries should fire when ready unless the observer has requested other wise.

(12) *Target number*. A number is selected for each target from the block of numbers assigned to the battalion unless a number has been specified by higher headquarters. The battalion, division artillery, artillery group, corps artillery, or army artillery may assign a number to a target. This number is combined with a two-letter prefix to indicate the unit which assigned the target number. The list of target numbers used will be kept readily available in order to avoid duplication (FM 6-20-2).

d. By omitting an element of the call for fire the observer is, in effect, requesting the standard for that item. For example, by omitting a request for fuze, the observer is requesting fuze quick in effect. When the S3 cannot fulfill the requirement of the call for fire because of ammunition, shortages or policies of the commander or for other

reasons, he so specifies in the fire order. For example, the following call for fire is received in the FDC: GRID 41423617, DIRECTION 1460, INFANTRY PLATOON IN OPEN. VT IN EFFECT, PLATOON LEFT, ADJUST FIRE. The S3 decides that fuze time will have to be used for this mission. He issues the following fire order: BATTALION ALFA, USE GFT, LOT XRAY YANKEE, CHARGE 5, FUZE TIME IN EFFECT, 4 ROUNDS, TARGET ALFA FOXTROT 2401. Based on this call for fire and the fire order each of the batteries will fire battery four rounds at center range in fire for effect; Battery A will conduct the adjustment and will fire the center two pieces sequentially, from left to right, using shell HE and fuze quick. Corrections known for LOT XRAY YANKEE, CHARGE 5 will be used, and each round will be fired by the battery when ready.

e. The standards for those elements of the fire order that have standards are as follows:

Element	Standard
Method of fire or adjusting battery.	CENTER ONE ROUND.
Distribution	PARALLEL.
Projectile	SHELL HE.
Fuze	FUZE QUICK.
Range spread or zone	CENTER RANGE.
Lateral spread	CENTER DEFLECTION.
Time of opening fire	WHEN READY.

18-16. Announcing and Recording the Fire Order

★ *a.* The fire order is announced to all personnel in the fire direction center. Each computer, except when actively engaged in another mission, records the fire order on DA Form 3622, as shown in figure 18-1.

b. The batteries to fire in effect, the adjusting battery, the number of rounds, and the target number of the fire order (para 18-15*b* (1), (2), (9), and (12) and any other elements which differ from the call for fire are transmitted to the observer. In the example in paragraph 18-15*e*, BATTALION ALFA, TIME IN EFFECT, 4 ROUNDS, TARGET ALFA FOXTROT 2401 would be sent to the observer. In precision fire, only the unit firing and target number would be sent; e.g., BRAVO REGISTRATION POINT 1.

c. When DANGER CLOSE is included in the call for fire, the range probable error, in meters,

will be included as the last element of the message to observer.

18-17. Determining, Recording and Transmitting Preliminary Fire Command

★ *a.* Immediately on receiving call for fire and the fire order, computers determine, transmit to the battery, and record all fire commands except those determined from the chart and graphical equipment. For example, the call for fire GRID 43211234, DIRECTION 1430, VEHICLE PARK, ADJUST FIRE is received and the fire order BATTALION, BRAVO, USE GFT, LOT XRAY YANKEE, CHARGE 5, 4 ROUNDS, TARGET ALFA FOXTROT 2432 is given. By examining the recorded call for fire and the fire order, the adjusting battery (B) computer determines and records the following on DA Form 3622 (fig. 18-1).

(1) *Battery adjust.* The fire order indicates that the battalion will fire and Battery B will adjust.

(2) *Shell HE.* By omission of the type of projectile in both the call for fire and the fire order, the use of shell HE is implied.

(3) *Lot XY.* The fire order indicates the use of lot XY.

(4) *Charge 5.* The fire order indicates the use of charge 5.

(5) *Fuze quick.* By omission of fuze in both the call for fire and the fire order, the use of fuze quick is implied.

(6) *Center one round.* Simultaneous fire by the center platoon of the adjusting battery is implied by omission of a method of fire in the observer's call for fire and the fire order. Battery B was designated in the fire order to conduct the adjustment. The computer designates only the center two pieces to fire one round during the adjustment.

(7) *Battery 4 rounds in effect.* The fire order specifies four rounds in effect.

b. The procedure for the nonadjusting batteries is the same as that in *a* above except the fire commands must include DO NOT LOAD; e.g., BATTERY 4 ROUNDS, DO NOT LOAD. The transmission of commands to nonadjusting batteries together with DO NOT LOAD permits preparation of the ammunition and laying the pieces in the

REPLACES DA FORM 6-16, 1 AUG 62, WHICH IS OBSOLETE.

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approximate direction to the target to minimize changes when the command to fire for effect is received.

c. The computer transmits all fire commands to the firing battery in the proper sequence as they are determined.

18-18. Determining and Recording Chart Data (Using Aluminum Range Deflection Protractor)

a. Initial chart data for all batteries to fire are determined by the horizontal control operator. The HCO announces range and deflection to each computer concerned by saying, for example, BRAVO RANGE 6600, DEFLECTION 3213.

b. The data for the adjusting battery are announced first. The SOP should designate the sequence to be used for nonadjusting batteries.

c. Data are determined and announced during adjustment for the adjusting battery only. When fire for effect is called for corrected chart data is announced for all batteries.

18-19. Determining and Announcing Site

a. Using the graphical site table, the vertical control operator computes the site for each battery to fire and records the computed site.

b. When each computer desires site, he requests it by saying, for example, SITE BRAVO. The VCO announces the site to each computer as requested by saying, for example, SITE BRAVO, PLUS 5. The computer repeats SITE BRAVO, PLUS 5 to the VCO to insure that the correct site has been received.

18-20. Determining and Recording Fire Commands Based on Chart Data

After receiving the chart data, the computer determines and announces the following data:

a. *Deflection.* The computer adds the deflection correction (if any) determined from the deflection correction scale to the chart deflection and announces the total as DEFLECTION (so much). The deflection correction remains constant throughout a low-angle mission.

b. *Quadrant Elevation.* The computer determines the elevation by placing the hairline over the chart range and reading the elevation under the elevation gageline. If no elevation gageline has been constructed, the elevation is read under the hair-

line. He then adds the site, determined by the VCO, to the elevation and announces the sum as QUADRANT (so much).

★c. *Computer's Records.* The computer records the data announced by the HCO and VCO and the fire commands on the FDC Computer's Record (DA Form 3622, fig. 18-1).

18-21. Measuring and Announcing the Angle "T"

a. If an adjustment is to be made, the HCO determines the size of the angle T to the nearest 10 mils, based on the direction given in the call for fire. This operation is performed after the initial data have been read from the chart. The HCO may determine the size of the angle T by measuring or computing it.

b. The size of the angle T to the nearest 100 mils is announced to the observer when it is 500 mils or greater. The size of the angle T may be requested by the observer at any time.

18-22. Procedure to Correct a Misorientation of Target Grid

If the observer sends a direction which is in error, the resulting error in orientation of the target grid (DA Form 6-53) should be corrected when it is large enough to cause the observer difficulty in adjusting.

a. In figure 18-2, the observer's first correction is ADD 400. The chart operator moves the target pin to a point equivalent to 400 meters up the OT line, and a round is fired with the data obtained.

b. The observer's next correction of RIGHT 200 indicates that the reported direction is in error. The chart operator moves the target pin to a point equivalent to 200 meters right of its last location and notes the position of the constructed line shot.

c. While a round is being fired with these data, the chart operator rotates the target grid until the arrow is parallel to the line formed by the previous line shot and the constructed line shot. The target grid is now oriented correctly. When the next observer correction is received, the target pin is moved from the chart location of the last round fired.

18-23. Procedure During Fire for Effect

a. When fire for effect is requested, the HCO determines and announces chart data for all batteries that are to fire.

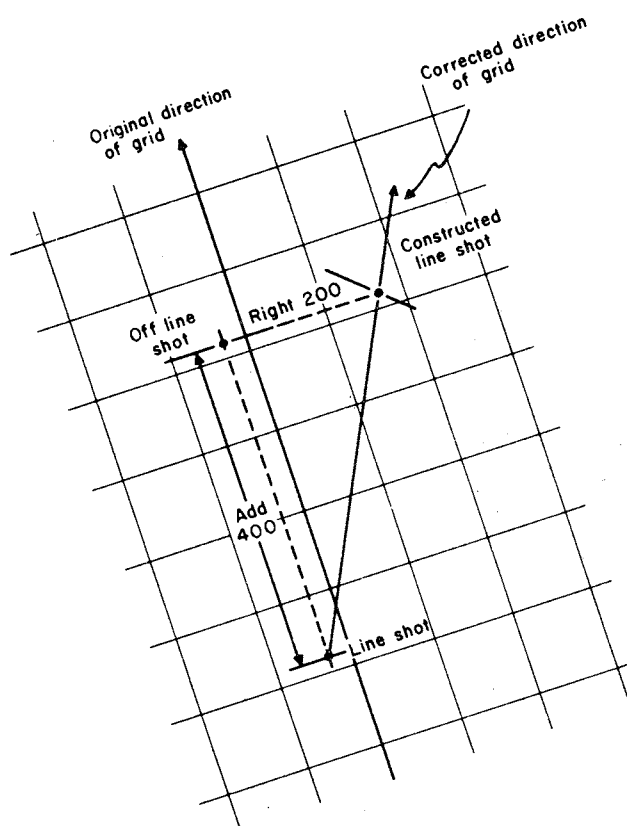


Figure 18-2. Correcting a Misorientation of the target grid.

b. The adjusting battery computer announces to the nonadjusting battery computers any change in fuze and the total correction to height of burst made during adjustment. For example, if in a fuze time mission, the observer's total height-of-burst correction during adjustment was down 10 meters, the adjusting battery computer would announce **CORRECTIONS, DOWN 10**. If no changes in fuze or correction to height of burst were made, the adjusting battery computer would announce **CORRECTIONS, NONE**.

c. All computers convert the chart data to firing data. Fire commands, including the method of fire specified in the fire order and the firing data, are announced to the firing battery.

d. When a range spread or one-half range spread has been directed in the fire order, the batteries will fire at different ranges. All chart data will be determined at center range. Normally, the adjusting battery computer will determine firing data based on the chart data announced by the horizontal control operator. One nonadjusting

battery will fire beyond center range, and the other will fire short of center range. The nonadjusting battery computers will add or subtract 50 meters or 100 meters, whichever is appropriate, to the chart range announced by the horizontal control operator. The nonadjusting battery computers determine firing data based on the modified chart range and the announced chart deflection. A procedure for a two-battery mission should be established so that all personnel, including observers, will know whether the nonadjusting battery is to fire beyond, or short of, the adjusting battery.

e. Each battery fires for effect as soon as it is ready, except when delayed fire for effect is desired. Delayed fire for effect may be used to advantage for any target consisting of personnel who must return to complete a specific job and for firing on an adjusting point where a target must appear; for example, engineer construction, such as bridges or crossroads frequently used by vehicles or personnel. Time-on-target procedures (para 18-30) can be used in these situations.

f. When the first rounds are fired, the firing battery reports **SHOT** to the fire direction center. **SHOT** is transmitted to the observer, who reads back **SHOT**. When the last battery to fire has reported **ROUNDS COMPLETE**, a message is transmitted from the battalion FDC to the observer as **ROUNDS COMPLETE** and he acknowledges with **ROUNDS COMPLETE**.

g. When the observer sends **END OF MISSION (EM)** and the results of the mission, the message is read back and recorded at the battalion fire direction center.

★h. The battery computers record the observer's report and, on completion of the mission, announce to the battery **END OF MISSION, TARGET (so-and-so)**. **END OF MISSION, TARGET (so-and-so)** is entered on the firing battery Recorder's Sheet (DA Form 3623) for future reference. At the completion of a mission, the battery computers, using DA Form 3622, and the recorder, using DA Form 3623, complete the ammunition record.

18-24. Multiple Fire Missions

a. Two fire missions can be processed in the battalion FDC simultaneously. All calls for fire

received at the FDC are acknowledged and recorded. When a battalion fire mission is in process and another mission is received, the mission is recorded by a second radiotelephone operator and is plotted by the vertical control operator in order for the S3 to examine it and reach a decision to fire. If the target is suitable for attack by a battery, the S3 should assign the mission to a battery FCD to be processed. Since only two fire missions (one per chart) can be conveniently processed concurrently in the battalion FDC, the S3 must make a decision when two or more requests (requiring more than one battery) are in the fire direction center. The S3 may stop firing a mission in order to attack a more important target, he may take the mission and notify the observer that there will be a delay, he may call on an attached or reinforcing battery, he may request the fire through higher headquarters, or he may decide the target is not sufficiently important to be attacked and treat the call for fire only as intelligence information and so inform the observer.

b. If a battalion mission requiring adjustment is in process and a call for fire is received which requires the use of only one battery, the S3 may assign the new mission to one of the nonadjusting batteries at once. The S3 would order the selected battery **SUSPEND ON TARGET ALFA FOXTROT 2205, FIRE MISSION**. The call for fire, which has already been recorded, would be repeated to the selected battery computer. A fire order for the mission would be announced. **END OF MISSION** followed by the new call for fire would be announced by the computer to the firing battery. If the battery should complete this mission before the mission of target **ALFA FOXTROT 2205** is in fire for-effect status, the S3 might order this battery to **RESUME ON TARGET ALFA FOXTROT 2205**.

18-25. Registration

Normally, the S3 supervises registrations. Registrations may be conducted by the battery when directed by battalion. To insure uniform application of corrections, the officer who conducts the registration immediately transmits the correction to all batteries and to the battalion fire direction center. The corrections are not applied until the S3 so directs. Computers maintain a record of current GFT settings and deflection corrections.

18-26. Procedure Using Time Fire

A 20-meter height of burst is a mean height suitable for all cannon artillery and will produce effective results without an excessive number of graze bursts or high airbursts because of the vertical probable error. When a time fuze is being used and a fire command including **DO NOT LOAD** is received at the firing battery, the fuze is not cut until a method of fire that permits loading of the weapon has been received. This procedure will preclude the setting of the fuze more than once if a different fuze setting is required when the final time is announced.

a. When time fuze is ordered in effect, either by the observer in the call for fire or by the S3 in the fire order, the adjustment is conducted with fuze quick. When the appropriate range-bracket (normally 100 meters) is split or a range correct spotting obtained, the observer will request time fuze and the adjustment of height of burst is conducted.

b. The computer determines the fuze setting for time fuze by placing the hairline of the GFT over the chart range and reading the fuze setting under the time gageline. If no time gageline has been constructed, the fuze setting is read corresponding to the elevation to be

fired. The fuze setting is announced as TIME (so much).

c. For the initial rounds of time fuze an angle of site, based on a vertical interval of 20 meters and the initial GT (chart) range, must be computed and added to the site computed for the ground location. Determination of this angle of site is simplified by using the 100/R scale on the GFT. The value of 100/R is a function of range and indicates the number of mils required to move the burst 100 meters vertically or laterally. 100/R is determined at the initial chart range. Since only a 20 meter height of burst is desired in time fire, only 0.2, or one-fifth, of 100/R is required. For example, when the range to the target is 6,000 meters the 100/R factor is 17 mils. 0.2, or one-fifth, of 17 is 3.4 mils, thus 3 mils must be added to the site to achieve a 20 meter height of burst. Complementary angle of site for the increased vertical interval is insignificant and is ignored.

d. The computer determines the angle of site for the height of burst and combines it with the site announced by the VCO and the elevation to determine the quadrant elevation.

e. When a height of burst correction is given by the observer, the computer converts the correction to a correction to fuze setting by determining, from the GFT, the change to fuze setting for a 10 meter change in height of burst and multiplying it by the number of 10 meter increments in the observer correction. For example, using charge 5 and a fuze setting of 17.5, the change to fuze setting for a 10 meter change in height of burst is 0.12. Assuming a height of burst correction of UP 40 the correction to fuze setting is $4 \times 0.12 = 0.48$ or -0.5 . Applying -0.5 to 17.5, a fuze setting to fire of 17.0 is determined. Assuming the observer's next correction to be DOWN 20, FIRE FOR EFFECT, the correction to fuze setting is $2 \times 0.12 = 0.24$ or $+0.2$. Applying this correction to the last fuze setting fired, 17.0, the new time to be fired is $17.0 (+0.2) = 17.2$. Height of burst corrections by the observer are announced to the nearest 5 meters. Δ FS/10M HOB is determined at the initial fuze setting.

f. Because fuze quick is used during the adjustment, the initial fire commands to the adjusting battery will state, as part of the

method of fire, the number of time fuzed rounds to be used in fire for effect. Typical fire commands for an adjusting battery would be, BATTERY ADJUST, SHELL HE, LOT XRAY YANKEE, CHARGE 5, FUZE QUICK, CENTER ONE ROUND, BATTERY 3 ROUNDS TIME IN EFFECT, DEFLECTION 3132, QUADRANT 345.

g. For purposes of refinement data or repeating fire for effect, the observer may desire to change the mean burst location. When this is the case the following procedures will apply:

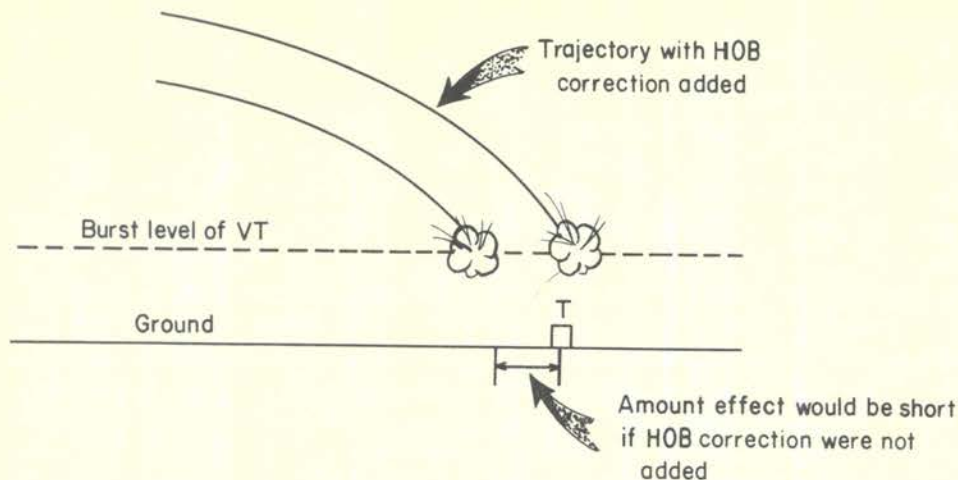
(1) *Range and/or deviation correction.* The HCO will plot the corrections and determine new chart data. The computer will determine new firing data and the Δ FS value for the total height of burst correction determined during the adjustment must be applied to the new fuze setting.

(2) *Height of burst correction.* Because a change in fuze setting to correct the height of burst will cause both a range and deviation change, the amount depending on the size of angle T, all corrections to height of burst after the initial fire for effect must be applied to total site using 100/R.

(3) *Range and/or Deviation and Height of Burst Correction.* The procedures outlined in (1) and (2) above must be used.

18-27. Procedure Using VT Fuze

a. When VT fuze is used, as when time fuze is used, an additional angle of site, 20/R, must be added to the site determined for the ground location. Application of this additional angle of site compensates for the shortened range that would result if the fuze functioned on a trajectory determined for a ground impact location (fig. 18-3). The height of burst obtained with VT fuzes varies in different types of terrain and with different angles of fall, resulting in a varying range effect. If an unsatisfactory range results, the observer must make a range correction to bring the effect to the desired location. For future missions in the same area, a similar correction may be applied for fire for effect with VT fuze. There is no need to compensate for the shortened range, in high-angle



★Figure 18-3. Result of a height-of-burst correction to VT fuze effect.

fire since the descending branch of the trajectory is nearly vertical.

b. The height-of-burst correction added to the site is determined in the same manner as described in paragraph 18-26a.

c. When VT fuze is to be used in fire for effect, adjustment is made with fuze quick in order to facilitate spotting. The fire commands to the adjusting battery will state, as a part of the method of fire, the number of VT fuzed rounds to be used in fire for effect to expedite the delivery of fire for effect. Typical fire commands for an adjusting battery would be BATTERY ADJUST, SHELL HE, LOT XRAY ZULU, CHARGE 5, FUZE QUICK, CENTER ONE ROUND, BATTERY 3 ROUNDS VT IN EFFECT, DEFLECTION 3359, QUADRANT 352.

d. The computer computes the height-of-burst correction (using 100/R at initial chart range) and applies it as part of site on entering fire for effect. Nonadjusting battery computers will determine the height-of-burst correction and apply it in the initial commands, which are sent together with DO NOT LOAD as a part of the method of fire.

e. When VT fuzes are used and the source of data is tabular firing tables or graphical equipment which includes time-of flight data, a fuze setting corresponding to the time of flight to the target is determined. The time of flight to

the target is that corresponding to the elevation to be fired. If the time of flight to the target is not a whole number, the next lower whole number is used. For example, if the time of flight corresponding to the elevation to be fired is 24.2 seconds; the fuze setting for the VT fuze is 24 seconds. This is announced at TIME 24.0.

★f. When VT fuzes are used and the source of data is graphical equipment which does not include time of flight data, the fuze setting for the VT fuze is that fuze setting for MTSQ that corresponds to the elevation to be used. If this fuze setting is not a whole number, drop the fraction.

g. Since fuze quick is used in adjustment, the fire command for time is announced with fire-for-effect data for the adjusting battery. A fuze setting command is included in the initial commands for nonadjusting batteries. If the observer reports that VT fuzes are bursting on impact, the fuze setting for the VT fuze is decreased by 1.0.

★h. When the XM5 desensitizing cap is used with the M513 series fuzes, 20/R need not be added because the height of burst is reduced to approximately 5 meters.

18-28. Procedure for Mission by Air Observer

a. The air observer, with no fixed location,

normally omits direction in his call for fire. He will usually adjust with respect to the gun-target line. If grid coordinates are used initially to locate the target, the chart operators plot the grid and determine the chart data. The target grid is then centered on this plot and oriented with the 0-3200 line parallel to the arm of the range-deflection protractor. The vertex of the range-deflection protractor is at the *adjusting battery* pin and the edge is against the pin at the initial target location. The observer's first correction is plotted with the target grid oriented as described above, and the chart data are determined. The target grid need not be reoriented after subsequent corrections unless there has been a change of 200 mils or more in direction of fire during the mission. If necessary, the target grid is reoriented by rotating (using the target pin location as a pivot point) until the 0-3200 line of the target grid is again parallel to the arm of the range-deflection protractor.

b. To plot a target location as a shift from a registration (known) point, the chart operator must center the target grid over the registration point and orient the 0-3200 line parallel to the center battery-registration point line. The observer's shift is plotted, and the chart data are determined. The target grid is then reoriented parallel to the *adjusting battery*-target line. Thereafter, the target grid need not be reoriented during the mission unless the direction of fire changes more than 200 mils.

c. The target grid may also be oriented with respect to a reference line, such as a railroad, or the direction announced by the observer. In this case, the target grid is centered over a pre-designated point, and the 0-3200 line is oriented parallel to the reference line. The observer's corrections are with respect to the reference line; so the target grid needs no reorientation.

d. When the observer's call for fire includes MARK CENTER OF SECTOR, the target grid is centered over the point selected as the center of sector and oriented with the 0-3200 line parallel to the *adjusting battery*-target line. After the observer's shift from this point is plotted, the procedures outlined in *b* above are followed.

18-29. Procedure When Ground Observer Is Moving Rapidly

a. Occasionally, a ground observer, especially one mounted in a tank, finds it necessary to adjust with respect to the gun-target line. The fire direction procedures involved are the same as those prescribed for the air observer (para 18-28a and b.)

b. When an observer is moving rapidly while adjusting on the OT line, his OT direction may change considerably during a mission. If the observer does not change the direction in a subsequent correction, the FDC will change it, if necessary, using the procedure described in paragraph 18-22.

18-30. Procedure for Time-on-Target Missions

a. Time on target (TOT) is a special technique of firing the pieces of several units so that the projectiles of all the units firing arrive at the target at the same time. This technique gains the full value of the element of surprise. The time on target may be set by giving the time of day that fire is to be delivered. For example, the order may state TIME ON TARGET is 0915 HOURS (TIME IS 0905 _____ NOW). Time on target may also be ordered as TIME ON TARGET IS (so many; MINUTES FROM _____ NOW. Generally, 10 minutes in the foregoing orders will give all units sufficient time.

b. The target is plotted and firing data and fire commands are determined as usual except for the method of fire. The battalion S3 will include AT MY COMMAND, TIME ON TARGET in the fire order for time-on-target missions. The fire commands initially transmitted to the firing battery will include DO NOT LOAD. At the appropriate time, the method of fire is changed to include AT MY COMMAND, TIME ON TARGET (so many) MINUTES FROM _____ NOW. Each battery executive officer coordinates the time of loading so that the rounds are in the chambers for the shortest possible time prior to firing and reports when the battery is ready. The time at which a battery will load can be determined by subtracting the time of flight plus 30 seconds from the time on target. The time of flight should be sent to the executive officer if the fire commands do not include a fuze setting.

c. To coordinate the firing of all batteries, the battalion S3 starts a time count at the appropriate time, counting by seconds starting approximately 10 seconds before the battery with the longest time of flight must fire. Each battery is given the command FIRE when the battalion S3 announces the time in his counting which corresponds to the time of flight for the battery plus 2 seconds. This 2 seconds is added to the time of flight to allow for the time-lag between the announced count and the actual firing of the pieces.

d. For example, the following message has been received from a division artillery fire direction center:

THIS IS (call sign), FIRE MISSION, BATTALION, TARGET ALFA FOXTROT 2101, INFANTRY BATTALION ASSEMBLY AREA, VT, 2 ROUNDS, TIME ON TARGET IS 10 MINUTES FROM NOW.

The battalion S3 starts his stopwatch at the command NOW and begins his count by announcing, at the appropriate time, "TIME ON TARGET IS 60 SECONDS FROM NOW 50____40____30, 29, 28, 27, 26," etc, until all batteries have fired. The computer of a battery which has a time of flight of 13 seconds for this target would command fire at the announced count of 15.

18-31. Report on Firing to Battalion S2

The chief computer will report all missions fired to the battalion S2 as soon after the end of the

mission as possible. For example: BATTALION FIRED 3 ROUNDS ON 100 INFANTRY DIGGING IN AT 60053687, ESTIMATE 20 CASUALTIES, REMAINDER WITHDRAWING.

18-32. Records

★a. The battery computers will maintain a temporary file of FDC Computer's Records (DA Form 3622) for possible future reference.

b. A blackboard or sheet of acetate may be used for posting current GFT settings, registration and met data, and any other information of immediate use to the fire direction personnel. A record of registration and met data as well as velocity errors developed with specific ammunition lots should be kept for reference.

c. The battalion chief computer and the battery computers should maintain a temporary file of records of precision fire.

d. The computer maintains a temporary file of data sheets for all prearranged fire sent to the battery.

e. The battery computers maintain a current record of all ammunition present in the battery. If necessary, the computer's record may be supplemented in order to make the record complete.

f. The battalion chief computer keeps a current master ammunition record that will be a consolidation of the ammunition records of the battery computers plus the amount of ammunition in the battalion train.

Section IV. BATTERY FIRE DIRECTION

18-33. General

a. The battery executive officer is responsible for the control of the firing battery. This responsibility extends to the production of firing data and fire commands when the battery fire direction personnel are responsible for processing a mission. The executive officer exercises control of the firing battery from any position in the firing battery area that he chooses to occupy.

b. The battery fire direction center is the installation within the firing battery where firing data is determined. The battery fire direction center is manned by personnel assigned to the firing battery headquarters.

c. A battery in a battalion that normally exercises technical fire direction will determine fire commands only when—

- (1) Operating independently.
- (2) Directed to do so by the S3.

d. Firing charts—one or two, the number being left to the discretion of the commander—are maintained at the battery. If only one chart is maintained, it should be a grid sheet supplemented by a 1:50,000 map.

18-34. Procedure at the Battery When the Battalion Is Determining Fire Commands

a. When fire commands are being produced at the battalion FDC, the commands are transmitted to the battery fire direction center by the computer at the battalion fire direction center. The executive officer is responsible that the fire commands are received, recorded, read back, and relayed to the pieces. Considering the state of training of his unit, the executive officer must organize his personnel so that the fire commands are relayed to the pieces rapidly and accurately. A wire bridge may connect the radiotelephone operator's telephone and the computer's telephone in the battery FDC, enabling the computer in the battalion FDC to send commands directly to the guns. If a wire bridge has not been established, or the radiotelephone operator is receiving commands over the radio, the radiotelephone operator reads back the commands to the battalion fire direction center. The computer in the battery FDC records the commands and relays them to the pieces. In any case, the recorder at the gun po-

sition records the commands and reads them back to the FDC so that the executive officer (XO) can hear the commands and thereby control the fire and the chiefs of sections can check their sections. The executive officer (or assistant executive officer or chief of firing battery) must supervise the operations of the computer and the recorder. The executive officer himself may transmit the fire commands to the pieces and may do so from any position in the firing battery area that affords him the best control of firing battery operations

b. During lulls in firing, the battery chart operator(s) and computer receive, from the battalion FDC, data for the construction of the firing chart and current registration and met data. The GFT settings and deflection correction scales are kept current so that the battery can determine fire commands when required.

18-35. Procedures When the Battery Is Producing Fire Commands

When the battery is required to produce fire commands, appropriate personnel of the firing battery headquarters constitute the FDC and assume the functions of their battalion counterparts; i.e., the executive officer (or whoever is in charge of the firing battery at the time) assumes the duties of the S3, the battery computer assumes the duties of the computer in the battalion FDC, and so forth.

Section V. COMMUNICATIONS

18-36. General

a. Separate radio and wire systems are installed to provide the communications necessary for fire direction. These systems should parallel each other so far as possible to provide an alternate means of communication if either system should fail. The radio and wire systems can readily be adapted to units regardless of caliber or mission. All FDC personnel should be trained in both communication and gunnery techniques. Neither wire nor radio can be considered the primary means of communication, since the presence of both types of communication permits a selection of the best means to meet any situation. Highest priority must be

given to installing the wire lines between the battalion FDC and the fire direction centers in the firing batteries. For detailed instructions pertaining to wire and radio communications, see FM 6-10.

b. Maximum use will be made of fire direction personnel to set up the communications within the fire direction center. For example, wire personnel normally will lay wire to a terminal near the fire direction center. The FDC personnel are responsible for the communications from the terminal to and throughout the fire direction center. Radio operators will remote the radios. The switchboard operator will

conduct the normal wire checks for those lines terminating in the switchboard.

18-37. Wire

The extent of the wire system installed depends on the length of time a position is occupied.

a. If a battalion position is occupied for a short period, lack of time may preclude developing the wire system beyond installing the fire direction lines to the batteries. In this case,

radio will carry traffic to liaison officers and forward observers.

b. If a battalion position is occupied for a sufficient length of time, a complete wire system is installed. The installation of wire is started on completion of reconnaissance. The system is expanded and improved until the unit displaces from the position. Wire circuits parallel the radio circuits. As the wire system is improved, radio traffic is reduced.

Section VI. SAMPLE MISSIONS

★18-38. One Battery, Fuze Time

a. General. A 155-mm howitzer (M109) battalion has established OP's and a registration has been conducted. The GFT setting derived from the registration is GFT B: Charge 5, Lot

XY, range 6900, elevation 380, time 24.9. The installation of wire lines to the OP's has not been completed.

b. *Procedures During Mission (As Prescribed by ACP 125). See figure 18-4.*

FO radiotelephone operator:	ALWAYS CIVIL 18, THIS IS ALWAYS CIVIL 46, FIRE MISSION, OVER.
FDC radiotelephone operator: to alert FDC personnel:	FIRE MISSION.
FDC radiotelephone operator:	ALWAYS CIVIL 46, THIS IS ALWAYS CIVIL 18, FIRE MISSION, OUT.
FO radiotelephone operator:	GRID 983642, OVER.
FDC radiotelephone operator:	GRID 983642, OUT.
FO radiotelephone operator:	DIRECTION 2140, OVER.
FDC radiotelephone operator:	DIRECTION 2140, OUT.
FO radiotelephone operator:	INFANTRY WEAPONS COMPANY DIGGING IN, TIME IN EFFECT, ADJUST FIRE, OVER.
FDC radiotelephone operator:	INFANTRY WEAPONS COMPANY DIGGING IN, TIME IN EFFECT, ADJUST FIRE, OUT.

The chart operators plot the target. The location of the target is checked against no-fire lines and the location of friendly troops. The S3 decides how to attack the target and issues the fire order.

S3:	BRAVO, USE GFT, LOT XRAY YANKEE, CHARGE 5, 5 ROUNDS, TARGET ALFA FOXTROT 2501.
FDC radiotelephone operator:	BRAVO, 5 ROUNDS, TARGET ALFA FOXTROT 2501, OVER.
FO radiotelephone operator:	BRAVO, 5 ROUNDS, TARGET ALFA FOXTROT 2501, OUT.
Battery B computer (to battery):	BATTERY ADJUST, SHELL HE, LOT XRAY YANKEE, CHARGE 5, FUZE QUICK, CENTER ONE ROUND, BATTERY 5 ROUNDS TIME IN EFFECT.
Battery B telephone operator:	BATTERY ADJUST, SHELL HE, LOT XRAY YANKEE, CHARGE 5, FUZE QUICK, CENTER ONE ROUND, BATTERY 5 ROUNDS TIME IN EFFECT.
HCO:	BRAVO RANGE 7240.
Battery B computer:	BRAVO RANGE 7240.
HCO:	DEFLECTION 3229.
Battery B computer:	DEFLECTION 3229.
Battery B computer determines	and applies a deflection correction of L1.
Battery B computer (to battery):	DEFLECTION 3230.
Battery B telephone operator:	DEFLECTION 3230.
Battery B computer (to VCO):	SITE BRAVO ?
VCO:	SITE BRAVO, PLUS 3.
Battery B computer:	SITE BRAVO, PLUS 3.

Battery B computer adds the site, +3, to elevation 408 and announces the sum to the firing battery as quadrant.

Battery B computer (to battery): QUADRANT 411.

Battery B telephone operator: QUADRANT 411.

As time permits, Battery B computer will determine 100/R and 20/R and enter them on the computer's record for use during the adjustment of height of burst with time fuze.

Battery B telephone operator: SHOT.

Battery B computer: SHOT.

FDC radiotelephone operator: SHOT, OVER.

FO radiotelephone operator: SHOT, OUT . . . DROP 200, OVER.

FDC radiotelephone operator: DROP 200, OUT.

HCO: RANGE 7050.

Battery B computer: RANGE 7050.

HCO: DEFLECTION 3219.

Battery B computer: DEFLECTION 3219.

Battery B computer (to battery): DEFLECTION 3220.

Battery B telephone operator: DEFLECTION 3220.

Battery B computer (to battery): QUADRANT 395.

Battery B telephone operator: QUADRANT 395 . . . SHOT.

Battery B computer: SHOT.

FDC radiotelephone operator: SHOT, OVER.

FO radiotelephone operator: SHOT, OUT . . . RIGHT 30, ADD 100, OVER.

FDC radiotelephone operator: RIGHT 30, ADD 100, OUT.

HCO: RANGE 7140.

Battery B computer: RANGE 7140.

HCO: DEFLECTION 3220.

Battery B computer: DEFLECTION 3220.

Battery B computer (to battery): DEFLECTION 3221.

Battery B telephone operator: DEFLECTION 3221.

Battery B computer (to battery): QUADRANT 403.

Battery B telephone operator: QUADRANT 403 . . . SHOT.

Battery B computer: SHOT.

FDC radiotelephone operator: SHOT, OVER.

FO radiotelephone operator: SHOT, OUT . . . TIME, LEFT 10, DROP 50, OVER.

FDC radiotelephone operator: TIME, LEFT 10, DROP 50, OUT.

Battery B computer (to battery): FUZE TIME.

Battery B telephone operator: FUZE TIME.

HCO: RANGE 7090.

Battery B computer: RANGE 7090.

HCO: DEFLECTION 3219.

Battery B computer: DEFLECTION 3219.

Battery B computer adds 20/R, site, and elevation together to determine the quadrant to fire (395 + (+3) + (+3) = 401). As soon as quadrant has been sent to the battery he will note and record in appropriate block on the computer's record, the change to fuze setting for a 10 meter change in heights of burst (0.08).

Battery B computer (to battery): DEFLECTION 3220, TIME 25.3, QUADRANT 401.

Battery B telephone operator: DEFLECTION 3220, TIME 25.3, QUADRANT 401.

. . . SHOT.

Battery B computer: SHOT.

FDC radiotelephone operator: SHOT, OVER.

FO radiotelephone operator: SHOT, OUT . . . DOWN 10, FIRE FOR EFFECT, OVER.

FDC radiotelephone operator: DOWN 10, FIRE FOR EFFECT, OUT.

Battery B computer (to battery): BATTERY 5 ROUNDS.

Battery B telephone operator: BATTERY 5 ROUNDS.

Battery B computer applies a correction of +0.1 to the last time fired.

Battery B computer: TIME 25.4, QUADRANT 401.

Battery B telephone operator: TIME 25.4, QUADRANT 401 . . . SHOT.

FDC radiotelephone operator: SHOT, OVER

FO radiotelephone operator:	SHOT, OUT .
Battery B telephone operator:	ROUNDS COMPLETE.
Battery B computer:	ROUNDS COMPLETE.
FDC radiotelephone operator:	ROUNDS COMPLETE, OVER.
FO radiotelephone operator:	ROUNDS COMPLETE, OUT . . . END OF MISSION, ESTIMATE 25 CASUALTIES, REMAINDER DISPERSED, OVER.
FDC radiotelephone operator:	END OF MISSION, ESTIMATE 25 CASUALTIES, REMAINDER DISPERSED, OUT.
Battery B computer (to battery):	END OF MISSION, TARGET ALFA FOXTROT 2501.
Battery B telephone operator:	END OF MISSION, TARGET ALFA FOXTROT 2501.

18-39. Common Errors and Malpractices in the Fire Direction Center

a. The formation of proper habits in training and the use of independent checks are the means of eliminating the common errors and malpractices that occur in the fire direction center.

b. Common errors and malpractices in plotting are—

(1) Using improper scale of the coordinate scale.

(2) Using the yard scale instead of the meter scale.

(3) Plotting the grid from the wrong grid line in the wrong direction, when the firing chart is so placed that north is toward the plotter.

(4) Putting the center of the protractor over the wrong point.

(5) Reading azimuths 1,600 or 3,200 mils in error.

c. Common errors and malpractices pertaining to the range-deflection protractor, and the GFT are—

(1) Reading the wrong elevation or time gageline when more than one line is placed on a cursor.

(2) Failing to seat the vertex of the

range-deflection protractor against the pin in the battery position when data are being determined or against the pin in an OP or radar position for polar plotting.

(3) Reading the data on the GFT from a position other than directly above the index and scale, thus introducing parallax errors.

(4) Reading deflections from the deflection index of the wrong battery.

(5) Misreading the deflection.

★(6) Using the ballistic scale for the wrong charge.

(7) Reading drift instead of fork (F) or vice versa.

d. Common errors and malpractices with the target grid are—

(1) Miscounting in increments of 100 meters in plotting shifts on the grid.

(2) Failing to orient the target grid properly by using the azimuth scale, which is graduated in a counterclockwise direction.

(3) Failing to label or construct the north index correctly. This error is especially common when direction of fire is other than north.

(4) Reversing the observer's target location; for example, plotting FROM REGISTRATION POINT, RIGHT 500 as 500 meters left (or over, or short) of the registration point.

FDC COMPUTER'S RECORD															
For use of this form, see FM 6-40; the proponent agency is U.S. Continental Army Command.															
Battery B		Date 27 MAR		Time received 1025		Time completed 1038		Target number AF 2501							
Call for fire 46, FM, GRID 983 642, DIR 2140, INF WPN CO DIGGING IN, TIME IN EFFECT, AF Fire order: Unit(s) B Mf _____ Basis for corr USE GFT Distr _____ Shell _____ Lot XY Charge 5 Fuze _____ 5 rounds; spread _____ Time _____ Tgt no AF 2501				Df corr L1		INITIAL FIRE COMMANDS									
				Deflection 3229		BTRY Adjust				Sp instr					
				Range 7240 EL 408		Shell HE				Lot XY					
				Site +3 411		Charge 5				Fuze Q					
				100/R 14		20/R 3		Δ FS 0.08		Mf C(1) BTRY (5) TIME in eff		Df 3230			
										QE 411		Time Ammo exp (2)			
OBSERVER CORRECTIONS					SUBSEQUENT FIRE COMMANDS										
Shell, fz, mf	Dev	Range	Height	Sh, chg, fz, mf	Range	Chart df	Corr (L1)	Piece df	FS Corr	Time	HOB Corr	Site (+3)	EL	QE	Ammo exp
		-200			7050	3219	L1	3220				+3	392	395	(4)
	R30	+100			7140	3220	L1	3221				+3	400	403	(6) Q
Ti	L10			FzTi	7090	3219	L1	3220		25.3	+3	+6	395	401	(2)
				DIO, FFE BTRY (5)					+0.1	25.4				401	(32) Ti
EM, ESTIMATE 30 CASUALTIES REMAINDER DISPERSED															
DATA FOR REPLOT															
Coordinates				Altitude				Fuze				Target number			
AMMUNITION															
Type	HE	HE	PROP	PROP	M557	M564	M514								
Lot	X	Z	W	Y											
On hand	287	450	450	287	350	337	96								
Received															
Total															
Expended	38			38	6	32									
Remaining	249	450	450	249	344	305	96								

DA FORM 3622, 1 Aug 70

REPLACES DA FORM 6-16, 1 AUG 62 WHICH IS OBSOLETE.

Figure 18-4. Completed computers record fuze time mission.

CHAPTER 19

CONDUCT OF REGISTRATIONS

Section I. GENERAL

★19-1. Introduction

If all conditions of materiel and weather were standard, firing a cannon at a particular elevation would cause the projectile to travel the distance shown in the firing table corresponding to that elevation. Similarly, with the proper deflection set on the weapon (including the drift correction from the firing table), the projectile would burst on the gun-target line. However, standard conditions of materiel and weather seldom exist simultaneously; thus, the projectile will rarely hit the target when fired with standard data for the chart range and deflection. Survey, firing chart, materiel, and nonstandard atmospheric conditions may each contribute errors. The number of meters by which the projectile bursts over or short and right or left of the target is the combined effect of these errors. The magnitude of the cumulative error and the correction for that error can be determined by registration.

19-2. Purpose of Registrations

The purpose of a registration is to determine

the firing data (called adjusted data) that will place the mean burst location of rounds fired with that data at a point of known location. Registration data is used to determine corrections which, when applied, will compensate for the cumulative errors contained in survey, the firing chart, materiel, and nonstandard atmospheric conditions (chap 20).

19-3. Types of Registrations

The types of registration are—

a. Precision Registration. Precision registration is a technique for determining, by adjustment, the firing data that will cause the mean point of impact of a group of rounds to occur at a point of known location, called a registration point.

b. High-Burst and Mean-Point-of-Impact Registrations. A high-burst or a mean-point-of-impact registration is a technique for determining the mean burst location of a group of rounds fired with a single set of data.

Section II. PRECISION REGISTRATION

19-4. General

★*a.* A registration point is a point in the target area, the location of which is known on the ground and on the firing chart, on which a precision registration is conducted. If the target area is large, it may be desirable to use more than one registration point. Some of the characteristics of a good registration point are that it be—

- (1) Readily identifiable.
- (2) Located horizontally and vertically

close to the center of the target area or zone of action.

(3) Permanent or semipermanent in nature.

b. Only one piece, normally the base piece, is used to conduct a registration.

c. DA Form 6-12 (Record of Precision Fire) is the form used by fire direction personnel to compute and record data during a precision registration.

d. A precision registration is conducted in two phases—adjustment and fire for effect.

19-5. Adjustment Phase

a. The observer is normally directed to conduct a registration on a designated registration point. Occasionally, the observer may be required to select a registration point.

b. On receipt of the observer's call for fire, the horizontal control operator (HCO) determines and announces the chart range and deflection to the registration point. The vertical control operator (VCO) computes and announces site. The initial fire commands are determined by the computer and sent to the battery. Fuze quick is used throughout the adjustment.

c. The HCO plots the observer's corrections, using the target grid, and announces the chart data. The computer determines and announces the subsequent fire commands.

d. When the observer's correction is ADD (so much) or DROP (so much) and does not include a deviation correction, an observer deviation spotting of LINE is presumed at the FDC and an FDC deflection spotting is determined and recorded. The FDC deflection spottings determined during the adjustment may be used during fire for effect to establish one limit of a deflection bracket.

e. The adjustment phase is ended when—

- (1) The observer splits the proper range bracket.
- (2) A target hit occurs.
- (3) A spotting of RANGE CORRECT is made by the observer.

19-6. Determination of Angle "T"

a. The angle T is the angle formed at the target by the intersection of the gun-target line and the observer-target line.

b. At the beginning of a precision registration on a surveyed registration point, the HCO measures and announces the angle T to the nearest 10 mils. Normally, the announcement of the value of the angle T is made after the computer has sent the initial fire commands to the firing battery.

c. If the location of the registration point is not accurately known (i.e., when an observed

firing chart is used), the value of the angle T is determined upon entering fire for effect.

d. If the target grid is centered over the registration point and oriented on the observer's direction, the angle T is measured by placing the vertex of the range-deflection protractor against the battery pin and the left edge of the arm against the pin in the registration point. The value of the angle T is determined from the azimuth scale of the target grid between the point where the arm of the range-deflection protractor intersects the scale and 0 or 3200, whichever is appropriate.

e. The angle T may be computed by comparing the azimuth from the observer to the registration point with the azimuth from the battery to the registration point.

19-7. Fire for Effect Phase

a. Fire for effect is begun upon completion of the adjustment phase. During fire for effect, the firing chart is not used. Firing data are computed from the spottings reported by the observer.

b. Fire for effect is conducted with fuze quick until the correct deflection and adjusted elevation are obtained. When desired, a time registration is conducted with fuze time to determine the adjusted time (para 19-18—19-20).

19-8. Determination of FDC Spottings

Adjusted elevation and the correct deflection are determined with respect to the GT line. Observer spottings, made with respect to the OT line, must be converted to FDC spottings with respect to the GT line. The FDC spottings corresponding to a given observer spotting are dependent on the location of the observer with respect to the GT line (right or left) and the size of the angle T. An FDC spotting table (fig. 19-1) is provided to facilitate the determination of FDC spottings.

19-9. Factor S

a. The factor S is the deflection change in mils between two rounds that bracket the target and are 100 meters apart on the OT line (fig. 19-2). The value of the factor S depends on the range and the size of the angle T. A

decrease in range will increase the factor S. An increase in the size of angle T will also increase the value of the factor S.

b. When the observer obtains a 100-meter bracket on the OT line, it is assumed that a 1S deflection bracket exists. When the 100-meter bracket is split, the deflection read by the HCO should be within $\frac{1}{2}$ S of the correct deflection.

c. The values of $\frac{1}{2}$ S for all likely combinations of range and angle T have been computed

and placed in the $\frac{1}{2}$ S table (fig. 19-3). The values of $\frac{1}{2}$ S in the table are the computed values rounded to 2 or the nearest power of 2.

d. The $\frac{1}{2}$ S is determined as soon as the angle T for the mission is determined.

19-10. Correct Deflection

a. Deflection is correct when one of the following conditions has been satisfied:

- (1) A target hit is obtained.

FDC SENSING (SPOTTINGS)

Guns on left	Observer Sensing	1	100	500	800	1400	1601	1800	2400	2700	3100
		-99m	-499m	-799m	-1399m	-1600m	-1799m	-2399m	-2699m	-3099m	-3200m
	?R	?R	+R	+?	+?	+?	+?	+?	+?	+L	?L
	?L	?L	-L	-?	-?	-?	-?	-?	-?	-R	?R
	+LN	+L	+L	+L	+L	+L	-L	-L	-L	-L	-L
	+R	+R	+?	+?	+?	+L	+L	?L	-L	-L	-L
	+L	+L	+L	+L	?L	-L	-L	-?	-?	-?	-R
	-LN	-R	-R	-R	-R	-R	+R	+R	+R	+R	+R
	-R	-R	-R	-R	?R	+R	+R	+?	+?	+?	+L
	-L	-L	-?	-?	-?	-R	-R	?R	+R	+R	+R

FDC SENSING (SPOTTINGS)

Guns on right	Observer Sensing	1	100	500	800	1400	1601	1800	2400	2700	3100
		-99m	-499m	-799m	-1399m	-1600m	-1799m	-2399m	-2699m	-3099m	-3200m
	?R	?R	-R	-?	-?	-?	-?	-?	-?	-L	?L
	?L	?L	+L	+?	+?	+?	+?	+?	+?	+R	?R
	+LN	+R	+R	+R	+R	+R	-R	-R	-R	-R	-R
	+R	+R	+R	+R	?R	-R	-R	-?	-?	-?	-L
	+L	+L	+?	+?	+?	+R	+R	?R	-R	-R	-R
	-LN	-L	-L	-L	-L	-L	+L	+L	+L	+L	+L
	-R	-R	-?	-?	-?	-L	-L	?L	+L	+L	+L
	-L	-L	-L	-L	?L	+L	+L	+?	+?	+?	+R

Figure 19-1. FDC sensing (spotting) table

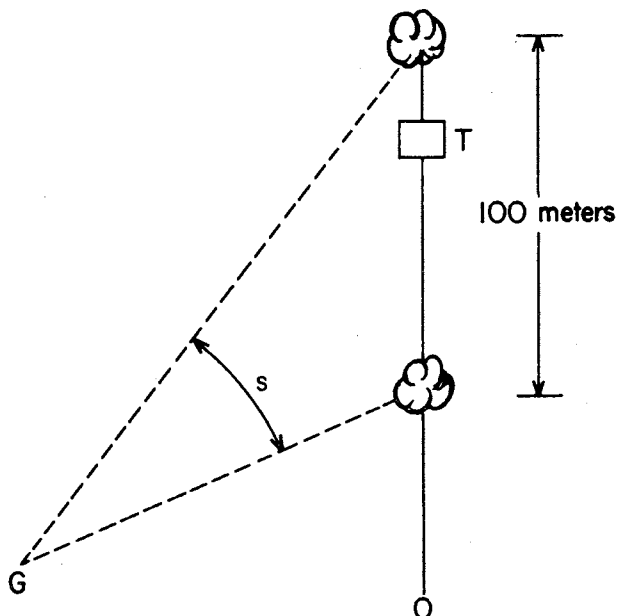


Figure 19-2. The factor S

 $\frac{1}{2}$ S TABLE

GT range in meters	Angle T in mils				
	0-99 3100-3200	100-499 2700-3099	500-799 2400-2699	800-1399 1800-2399	1400-1600 1601-1799
2000	2	4	8	16	16
3000	2	4	8	8	16
4000	2	2	4	8	8
5000	2	2	4	8	8
6000	2	2	4	4	8
7000	2	2	4	4	4
8000	2	2	2	4	4
9000	2	2	2	4	4
10000	2	2	2	4	4
11000	2	2	2	4	4
12000	2	2	2	2	4
13000	2	2	2	2	4
14000	2	2	2	2	2
15000	2	2	2	2	2

Figure 19-3. $\frac{1}{2}$ S table

- (2) A 2-mil deflection bracket is split.
- (3) Deflection spotting of left and right are obtained from the same deflection setting.

- (4) Deflection spottings of left and right are obtained from deflection settings 1 mil apart. (The last deflection is considered correct.)

b. The correct deflection is not necessarily the adjusted deflection (para 20-11).

19-11. Deflection in Fire for Effect

a. Deflection is not changed during fire for effect when the FDC deflection spotting is DOUBTFUL except in the situation described in e below.

b. When a definite FDC deflection spotting is obtained, previous FDC deflection spottings, including any obtained during adjustment, are examined to determine if a deflection bracket exists.

c. If a deflection bracket exists, the bracket is split or the deflection is changed $\frac{1}{2}$ S in the appropriate direction, whichever is the smaller change.

d. If a deflection bracket does not exist, the deflection is changed $\frac{1}{2}$ S in the appropriate direction.

e. If the adjusted elevation has been obtained but the correct deflection has not been determined, fire for effect is continued at the adjusted quadrant elevation, and the observer is required to give range and deviation spottings in meters. After two successive FDC spottings of DOUBTFUL and based on information from the observer—

- (1) The deflection may be considered correct.
- (2) An arbitrary shift may be made. Frequently, the arbitrary shift will yield a definite FDC deflection spotting.

Note. See paragraph 19-19 for a time registration.

f. After obtaining an adjusted elevation but not a correct deflection, the center of a 4-mil deflection bracket may be accepted as correct when speed, not refined accuracy, is essential.

g. Frequently, the terrain and other circumstances, such as large angle T, a small registration point, and wide dispersion, will combine to present difficulties in the adjustment of deflection. In this instance, as in any other observed fire situation, the observer usually is the best qualified to take action. The observer may see more than he can convey in the normal spotting. The S3 must be prepared to ask for and rely on the observer's report and judgment.

19-12 Use of Fork

The fork is the change in elevation required to move the mean point of impact of a group of rounds a distance equal to 4 range probable errors. In a precision mission, the fork used is that corresponding to the first elevation fired in the fire-for-effect phase. If the value of the fork is an odd number, it is increased to the next higher even value to facilitate splitting. (The correct value of the fork must be used in the computation of the adjusted elevation.)

19-13. Elevation in Fire for Effect

a. The first round in fire for effect is normally the result of an observer's correction of ADD (DROP) 50, FIRE FOR EFFECT. Based on the FDC range spotting of this round, the S3 will change the quadrant elevation by moving 1 even fork in the opposite direction and firing one round. This procedure is repeated, if necessary, until a fork bracket is established. This bracket is then split and firing is continued until three definite FDC range spottings are obtained. Definite range spottings are OVER and SHORT. The quadrant elevation is then changed $\frac{1}{2}$ fork in the direction opposite to the preponderance of the spottings. This will result in firing at one of the quadrant elevations which established the even fork bracket. Fire for effect is continued until two more definite range spottings are obtained, for a total of six.

b. The six rounds considered in the computation of the adjusted quadrant elevation are the three rounds which yielded definite spottings at the center of the bracket, the last two rounds which yielded definite spottings, and the round which established the even fork bracket and was fired at the same quadrant elevation as the last two rounds.

19-14. Computation of Adjusted Elevation

a. The computation of the adjusted elevation is based on the assumption that the six rounds considered fell in a normal dispersion pattern. The location of the mean point of impact of the six rounds with respect to the registration point may be computed based on the laws of probability and the size of the range probable error. A change in elevation that will place the mean point of impact at the registration point is computed.

b. The following formula is used to determine the elevation change to move the mean point of impact to the registration point:

$$\text{Elevation change} = \frac{\text{difference in number of overs and shorts}}{2 \times \text{number of rounds considered}} \times \text{fork.}$$

Example: The six FDC range spottings considered during fire for effect are four shorts and two overs. The fork is 6. Elevation change = $\frac{2}{(2 \times 6)} \times 6 = 1.0$ mil. The sign of the change is plus if the preponderance is short and minus if the preponderance is over.

c. The elevation change is applied to the mean of the quadrant elevations used during fire for effect, and the result is expressed to the nearest mil. Site is then subtracted from the adjusted quadrant elevation. The result is the adjusted elevation.

Example: During fire for effect, three FDC spottings were determined at quadrant 316 and three at 313. The elevation change is applied to the mean quadrant $314.5 \frac{(316+313)}{2}$. The adjusted quadrant is 316 ($314.5 + 1.0 = 315.5$ or 316). Site is +3 mils. The adjusted elevation is 313.

19-15. Example of a Registration

Figure 19-4 contains an example of a registration with fuze quick. The registration was conducted with a 155-mm howitzer (M109), using charge 4 green bag. There is no base piece displacement for range.

a. *Comment 1.* After the initial round is fired, the HCO measures and announces the angle τ as ANGLE τ 430, GUNS ON THE LEFT. The computer then enters the $\frac{1}{2}$ S table at the appropriate chart range (to the nearest listed value, 5000) and the appropriate angle τ (100-499) and determines the $\frac{1}{2}$ S to be 2 mils.

b. *Comment 2.* Firing data for rounds 2 through 4 are based on the HCO's plotting of the observer's corrections.

c. *Comment 3.* The observer's correction of ADD 100 from round 2 indicates that his spotting must have been SHORT LINE. Based on this observer spotting, and FDC deflection spotting of RIGHT is determined and recorded for round 2.

d. *Comment 4.* The value of the fork is deter-

mined at the first elevation in fire for effect—303 mils (QE 309—site + 6 = el 303). Fork is 4, and $\frac{1}{2}$ fork is 2.

e. *Comment 5.* The fourth round (first round in fire for effect) yields a definite FDC range spotting of OVER; therefore the fifth round is fired at a quadrant elevation 4 mils lower (1 even fork). This round yields a SHORT, thereby establishing the even fork bracket on the gun-target line. The bracket is split and rounds 6, 7, and 8 yield a preponderance of SHORT (—, +, —). The quadrant elevation is change $\frac{1}{2}$ fork opposite the preponderance, toward the OVER, at quadrant elevation 309. Rounds 9 and 10 yield two more OVER's. The adjusted quadrant elevation is computed with the three rounds fired at quadrant elevation 307 and the three rounds fired at quadrant elevation 309.

f. *Comment 6.* During fire for effect, the deflection (3197) is not changed until a definite FDC deflection spotting is obtained. The FDC deflection spotting of RIGHT from round 6 is compared to that obtained from round 2. Since no deflection bracket exists, the deflection is change by $\frac{1}{2}$ S in the direction opposite the last spotting obtained, to deflection 3199. Round 7 results in an FDC deflection spotting of LEFT. At this point, the registration has resulted in FDC deflection spotting of RIGHT at deflection 3197 and LEFT at deflection 3199. The correct deflection is 3198 (a 2-mil deflection bracket is split).

19-16. Target Hits

a. Occasionally, the observer will enter fire for effect as the result of a target hit. In this case there is no requirement to establish the fork bracket, because the target hit yields both an OVER and a SHORT FDC range spotting and the deflection fired is the correct deflection. The round which hit the target becomes the first round in fire for effect. Definite FDC range spottings are obtained from two more rounds fired at the same quadrant elevation. Now the possibility arises that no preponderance could exist (T, —, +). In this case, definite FDC range spottings must be obtained from three more rounds fired at the same quadrant elevation (for a total of six at the same quadrant elevation). If, after the two rounds are fired, a preponderance does exist (e.g., T, —, —), the quad-

RECORD OF PRECISION FIRE (FM 6-40)									
Date and time 10 JUNE 0800		Observer 24		Adjusting point REG PT 1		Battery A			
GFT setting GFT A :chg 4 ,lot RS ,rg 5090 ,el 301 ,ti						Deflection correction R17			
Chart data			Initial fire commands						
Deflection 3215		Corr 0		BP Adjust					
Range 5090		EI 313		Sh HE Lot RS					
Adjusted data		Si +6		Chg 4 Fz 0					
Deflection 3198		S/2 = 2		MF BP ①					
Elevation 301		F = 4		Df 3215					
Time		F/2 = 2		QE 319		Angle T 430			
Round no	Chart df	Df fired	Chart range	Time fired	EI or QE fired (+6)	Observer sensing or corrections	FDC sensings		
							Range	Deflection	
①	3215		5090		319	R50 - 200			
②	3189		4930		306	+100		R	
③	3198		5020		313	L20, -50, FFE			
④	3197		4970		309	+R	+	?	
⑤		(3197)			305	-L	-	?	
⑥		(3197)			307	-R	-	R	
⑦		3199			307	+LN	+	L	
⑧		(3198)			307	-L	-	CORR	
⑨					309	+R	+		
⑩					309	?R	+		
11					EM				
12									
13	Adjusted DE		3198 (2-mil bracket split)						
14	Mean RE		= 308.0						
15	EL CHANGE $\frac{4-3}{2 \times 10} \times 4$		= -0.7						
16	Adjusted QE		= 307.3	or 307					
17	SITE		=	-(+6)					
18	Adjusted EL		=	301					
19									
20									
21									
22									
23									
24									

DA FORM 6-12
1 OCT 64

REPLACES DA FORM 6-12, 1 APR 57, EXISTING SUPPLIES OF WHICH WILL BE ISSUED AND USED UNTIL 1 OCT 66 UNLESS SOONER EXHAUSTED.

Figure 19-4. Record of registration, fuze quick

rant elevation is changed $\frac{1}{2}$ fork opposite the preponderance and definite spottings are obtained from *three* rounds. In either case the elevation change is then computed and applied to the mean quadrant elevation to determine the adjusted quadrant elevation.

Example 1:

Round No.	Deflection fired	Chart range	QE fired	Observer corr	FDC spottings	
					Range	Deflection
1-----	3215	5090	319	R50-200		
2-----	3189	4930	306	T	- +	CORR
3-----	-----	-----	306	-L	-	
4-----	-----	-----	306	-R	-	
5-----	-----	-----	308	+R	+	
6-----	-----	-----	308	?R	+	
7-----	-----	-----	308	+R	+	

Preponderance is one OVER.

Mean QE is 307.0.

Elevation change is -0.3.

Adjusted QE is 307 ($307.0 + (-0.3) = 306.7$).

★**Example 2:**

Round No.	Deflection fired	Chart range	QE fired	Observer corr	FDC spottings	
					Range	Deflection
1-----	3215	5090	319	R50-200		
2-----	3189	4930	306	T	- +	CORR
3-----	-----	-----	306	-L	-	
4-----	-----	-----	306	+R	+	
5-----	-----	-----	306	?R	+	
6-----	-----	-----	306	-LN	-	
7-----	-----	-----	306	-R	-	

Preponderance is one SHORT.

Mean QE is 306.0.

Elevation change is + 0.3.

Adjusted QE is 306 ($306.0 + (+0.3) = 306.3$).

c. If a target hit is obtained while a fork bracket is being established, the procedure in a above is followed.

d. If a target hit occurs after the fork bracket has been established and a preponderance exists, the procedure in paragraph 19-13 applies. If a target hit occurs after the fork bracket has been split and no preponderance exists, three more definite FDC range spottings must be obtained from the same quadrant elevation. The elevation change is computed by using the spottings from six rounds.

19-17. PE Equal to or Greater Than 38 Meters

In general, the same registration procedures apply to all artillery regardless of caliber;

Note. Regardless of the number of target hits obtained, the normal procedure requires that spottings from six rounds be used in computing the elevation change.

b. The two examples below are other possibilities for the registration in paragraph 19-15.

however, when the value of the PE_r is equal to or greater than 38 meters, rounds fired as a result of ADD (DROP) 50, FIRE FOR EFFECT, may be wasted because of the large range probable error. In such cases, the observer should be notified at the start of the mission to call for fire for effect when a 200-meter bracket is split.

19-18. Time Registration, General

If nonstandard conditions affected the time of flight at the same rate they affect range and if all time fuzes functioned exactly alike, the fuze setting listed in the firing table corresponding to the adjusted elevation would be the adjusted time. If a number of rounds were fired with that fuze setting and with the ad-

justed quadrant elevation and deflection to the registration point, a zero height of burst would result. A zero height of burst is obtained when a number of rounds fired with the same fuze setting and quadrant elevation results in a mean height of burst at ground level. Because time fuzes are affected by storage conditions and manufacturer's tolerance and because time of flight varies at a different rate than range to nonstandard weather conditions, a time registration must be conducted to determine a fuze setting that will produce a zero height of burst for rounds fired with the adjusted elevation. This fuze setting is termed the adjusted time.

19-19. Time Registration Procedures

a. The time registration is conducted after the adjusted quadrant elevation has been determined with fuze quick. During the time registration, all rounds are fired with the adjusted quadrant elevation. If the correct deflection has not been determined prior to the determination of the adjusted quadrant elevation, the observer will spot the range and deviation of all graze bursts and the adjustment of deflection will continue during the time registration. (A precise FDC deflection spotting from an airburst is virtually impossible.) If the correct deflection has been determined before the start of the time registration, the observer will report only fuze action, AIR or GRAZE.

b. The registering piece is ordered to fire fuze time. The fuze setting for the initial round is normally the fuze setting listed in the firing table corresponding to the adjusted elevation. However, if an experience fuze correction is known, the initial round may be fired with a fuze setting corresponding to the adjusted elevation plus the experience fuze correction.

c. After the observer's first spotting, the fuze setting is changed 0.4 in an attempt to obtain a spotting in the opposite sense. If the spotting is AIR, the fuze setting is too short and 0.4 is added to the fuze setting. If the spotting is GRAZE, the fuze setting is too great and 0.4 must be subtracted from the fuze setting. This procedure of changing the fuze setting 0.4 is

continued until a spotting in the opposite sense is obtained. A 0.4 time bracket is thus established.

d. If the observer reports a height of burst in excess of 50 meters prior to the establishment of a 0.4 time bracket, a change in fuze setting larger than 0.4 may be appropriate.

e. After a 0.4 time bracket is obtained, the bracket is split. The fuze setting determined by splitting the 0.4 time bracket is the *trial time*. Three rounds are fired at the trial time.

f. After the observer spots the three rounds fired at the trial time, the preponderance of the spottings is determined. The fuze setting is change 0.2 in the direction opposite the preponderance and two rounds are fired. This procedure of adding or subtracting 0.2 from the trial time will always result in firing at the fuze setting which established the limit of the 0.4 time bracket in the direction opposite the preponderance at the trial time.

g. After the observer spots the two rounds fired at the fuze setting 0.2 away from the trial time, the adjusted time may be computed. The adjusted time is not a true time but is a term applied to a fuze setting. Henceforth, all fuze settings will be referred to as time; i.e., trial time, mean time, etc. The six rounds considered in the computation of the adjusted time are the three rounds fired at the trial time, the last two rounds fired, and the round fired with the same time as the last two rounds that established one end of the 0.4 time bracket. The formula for the computation of the adjusted time is—

$$\text{Adjusted time} = \text{mean time fired} \pm \frac{\text{difference in number of airs and grazes}}{2X \text{ number of rounds considered}} \times 0.4$$

The value of the time change expressed to the nearest 0.1 will always be 0.1 unless there is no preponderance. If the preponderance is AIR, the adjusted time is the mean time plus 0.1. If the preponderance is GRAZE, the adjusted time is the mean time minus 0.1. If there is no preponderance (equal number of AIR and GRAZE), the adjusted time is the mean time.

19-20. Example of a Time Registration

The following is an example of a time registration with a 155-mm howitzer (M109), charge

5, correct deflection 3211, adjusted elevation 320, adjusted quadrant elevation 324. The fuze setting corresponding to elevation 320 is 21.3.

Round No.	Deflection Fired	★Time Fired	QE Fired	Observer Spotting
12	3211	21.3	324	A (AIR)
13	----	21.7	324	A
14	----	22.1	324	G (GRAZE)
15 BP ③	----	21.9	324	A
16	----	----	----	G
17	----	----	----	A
18 BP ②	----	22.1	324	G
19	----	----	----	G

★*Comments:* Initial round is AIR; 0.4 is added to the time until a time bracket is established (AIR at 21.7; GRAZE at 22.1). The bracket is split and three rounds are fired at 21.9, resulting in two AIRS and one GRAZE—a preponderance of AIR. The time is increased 0.2, and two more rounds are fired at 22.1 (the time which established the graze end of the time bracket). The six rounds in fire for effect are the three rounds fired at 21.9 and the three rounds fired at 22.1. The preponderance of the six rounds is GRAZE; 0.1 is subtracted from the mean time, 22.0, to arrive at the adjusted time of 21.9.

19-21. Abbreviated Procedure for a Time Registration

The following procedure is one that may be used when speed or economy of ammunition takes precedence over accuracy, when only missions requiring adjustment are to be fired, or when subsequent registrations are to be fired in the same position with the same fuze-ammunition lot combinations. The procedure is appropriate when experienced personnel are firing under comparatively stable conditions and are able to judge the reliability of results. The technique is termed "the abbreviated procedure."

a. The trial time is determined as prescribed in paragraph 19-19a through e.

b. Two rounds are fired at the trial time.

c. If the two rounds fired at the trial time re-

sult in mixed spottings, the trial time is the adjusted time.

d. If the two rounds fired at the trial time result in the same spotting, the time is changed 0.2 in the appropriate direction (to the end of the 0.4 time bracket that resulted in a spotting opposite to that of the two rounds fired at the trial time) and one round is fired.

e. If the spotting of the one round fired at the appropriate end of the time bracket is opposite that of the rounds fired at the trial time, the adjusted time is the mean time.

f. If the spotting of the one round fired at the appropriate end of the time bracket is in the same sense as the rounds fired at the trial time, the registration may be invalid. (See para 19-26 for procedures to determine validity of the time registration when using the abbreviated procedure.)

g. Examples of the abbreviated procedure for a time registration are given in (1) and (2) below.

(1) Example 1.

Round number	Time	Spotting	Comment
1	19.6	A	Add 0.4.
2	20.0	G	Split the 0.4 time bracket.
3, 4	19.8	A, G	Trial time (19.8) is the adjusted time.

(2) Example 2.

Round number	Time	Spotting	Comment
1	19.6	G	Subtract 0.4.
2	19.2	A	Split the 0.4 time bracket.
3, 4	19.4	G, G	Subtract 0.2.
5	19.2	A	Adjusted time is 19.3.

Section III. VALIDITY OF REGISTRATIONS

19-22. General

a. An invalid registration may result from—

(1) An erroneous spotting by the observer, causing a false bracket in range deflection, or fuze setting.

(2) Errors at the fire direction center.

(3) Errors at the piece.

(4) Excessive dispersion.

b. Whenever a registration does not meet the requirements for validity, it must be continued until valid.

19-23. Verification of an Impact Registration

a. A registration which results in a single round of one spotting, such as five OVERS and one SHORT, five SHORTS and one OVER, one TARGET and five OVERS or SHORTS, is normally considered valid. However, if the S3 suspects that the one minority spotting is due to an error, he will verify the registration.

b. The procedure for verifying an impact registration is as follows:

(1) Move $\frac{1}{2}$ fork in the appropriate direction (add if the preponderance is SHORT; drop if the preponderance is OVER) from the last quadrant elevation fired and fire one verifying round.

(2) If the verifying round results in an FDC range spotting opposite to the preponderance, consider the registration valid. The verifying round is not considered in computing the adjusted quadrant elevation.

(3) If the spotting of the verifying round is in the same sense as that of the preponderance, fire two more rounds at the same quadrant elevation used to fire the verifying round. If the spotting of either of these two rounds is in the minority sense, the adjusted elevation is computed from the last three rounds fired and the three rounds fired at the quadrant previous to the verifying round. If both of these rounds are spotted in the same sense as the preponderance, the registration is invalid and a new fork bracket must be established and another fire for effect conducted.

c. Examples of verifying an impact registration are given in (1), (2), and (3) below.

(1) Example 1.

Round number	QE	FDC range spotting	Comment
1-----	339	+	Fork is 7. Move 8 (even fork).
2-----	331	-	Split bracket, fire ③.
3, 4, 5-----	335	+, +, +	All +, drop $\frac{1}{2}$ fork, fire ②.
6, 7-----	331	+, +	5 and 1, S3 decides to verify.
8-----	327	-	Registration is valid. Adjusted QE is 331.

(2) Example 2.

Round number	QE	FDC range spotting	Comment
1-----	339	+	Fork is 7. Move 8 (even fork).
2-----	331	-	Split bracket, fire ③.
3, 4, 5-----	335	+, +, +	All +, drop $\frac{1}{2}$ fork, fire ②.
6, 7-----	331	+, +	5 and 1, S3 decides to verify.
8-----	327	+	Fire ②.
9, 10-----	327	+, -	Compute adjusted QE, using rounds fired at QE 327 and 331. Adjusted QE is 328.

(3) Example 3.

Round number	QE	FDC range spotting	Comment
1-----	339	+	Fork is 7. Drop 8 (even fork).
2-----	331	-	Split bracket, fire ③.
3, 4, 5-----	335	+, +, +	All +, drop $\frac{1}{2}$ fork, fire ②.
6, 7-----	331	+, +	5 and 1, S3 decides to verify.
8-----	327	+	Fire ②.
9, 10-----	327	+, +	Registration is invalid. Drop even fork.
11-----	319	-	Split bracket, fire ③.
12, 13, 14-----	323	+, -, +	Drop $\frac{1}{2}$ fork, fire ②.
15, 16-----	319	-, -	Compute adjusted QE, using rounds fired at QE 323 and 319. Adjusted QE is 322.

19-24. Valid Time Registrations

a. A time registration is considered valid if any of the following combinations of spottings are obtained in fire for effect:

(1) Three AIR and three GRAZE.

(2) Four AIR and two GRAZE.

(3) Two AIR and four GRAZE.

b. If the spottings in the fire for effect phase of a time registration are five AIR and one GRAZE, the S3 must request the observer to report the mean height of burst. If the observer reports a mean height of burst of 15 meters or less, the registration is valid. If the mean height of burst is greater than 15 meters, the registration must be verified.

19-25. Verification of a Time Registration

a. A time registration which results in the following combinations of spottings must be verified:

(1) Five GRAZE and one AIR.

(2) One GRAZE and five AIR (mean height of burst is greater than 15 meters.)

b. The procedure for verification of a time registration is as follows:

(1) Change the time by 0.2 from the last time fired, adding if the preponderance is AIR and subtracting if the preponderance is GRAZE. Fire one verifying round.

(2) If the verifying round is spotted in the sense opposite the preponderance, consider the registration valid.

(3) If the verifying round is spotted in the same sense as the preponderance, fire two more rounds with the same time as the verifying round. If either of these rounds is spotted in the sense opposite to the preponderance, compute the adjusted time, using the last three rounds fired and the three rounds fired with a time 0.2 away from the time of the last three rounds. If both of the rounds fired with the same time as verifying round are spotted in the same sense as the preponderance, the registration is invalid and a new 0.4 time bracket must be established and another fire for effect conducted.

c. Examples of verifying time registrations are given in (1), (2), and (3) below.

(1) *Example 1.*

Round	Time	Spotting	Comment
1.....	14.1	A	
2.....	14.5	G	0.4 time bracket is established

3, 4, 5.....	14.3	G, G, G	
6, 7.....	14.1	G, G	
8.....	13.9	A	

Five G and one A, must be verified; subtract 0.2.
Registration is valid.
Adjusted time is 14.1.

(2) *Example 2.*

Round	Time	Spotting	Comment
1.....	14.1	A	
2.....	14.5	G	
3, 4, 5.....	14.3	G, G, G	
6, 7.....	14.1	G, G	Five G and one A, must be verified.
8.....	13.9	G	Spotting of verifying round same as preponderance. Fire two more rounds at 13.9.
9, 10.....	13.9	G, A	Compute adjusted time based on rounds 1, 6, 7, 8, 9, and 10. Adjusted time is 13.9.

(3) *Example 3.*

Round	Time	Spotting	Comment
1.....	14.1	A	
2.....	14.5	G	
3, 4, 5.....	14.3	G, G, G	
6, 7.....	14.1	G, G	Five G and one A, must be verified.
8.....	13.9	G	Spotting of verifying round same as preponderance. Fire two more rounds at 13.9.
9, 10.....	13.9	G, G	Registration is invalid. Re-establish 0.4 time bracket.
11.....	13.5	A	0.4 time bracket is established. Enter fire for effect.
12, 13, 14..	13.7	A, G, G	Preponderance is G.
15, 16.....	13.5	A, A	Four A and two G. Adjusted time is 13.7.

19-26. Verification of an Abbreviated Time Registration

a. If the two rounds fired at the trial time and the subsequent round fired at the end of the bracket are all AIR and the mean height of burst is 15 meters or less, the registration is valid.

b. If these same three rounds are all GRAZE or are all AIR with a mean height of burst greater than 15 meters, the registration may

be invalid. In this situation, the apparent adjusted time is the time that established the end of the 0.4 time bracket at which the last round was fired.

c. The apparent adjusted time is verified by changing the time 0.2 in the appropriate direction (adding if the last round is AIR and subtracting if the last round is GRAZE), and firing one verifying round.

d. If the spotting of the verifying round is opposite that of the last three rounds fired, the apparent adjusted time is considered verified.

e. If the spotting of the verifying round is the same as that of the last three rounds fired, one more round is fired with the same time as that of the verifying round. If the spotting of this round is opposite that of the preceding round, the adjusted time is the mean of the apparent adjusted time and the time at which the last two rounds were fired. If the spotting of this last round fired is still the same as that of the four preceding rounds, a new 0.4 time bracket must be established and a new fire for effect conducted.

f. Examples of the abbreviated procedure for an invalid time registration (suspected) are given in (1) and (2) below.

(1) Example 1.

Round	Time	Spotting	Comment
1-----	22.4	A	Add 0.4
2-----	22.8	G	Split the 0.4 time bracket.
3, 4-----	22.6	G, G	Subtract 0.2.
5-----	22.4	G	Apparent adjusted time is 22.4. Must be verified.
6-----	22.2	A	Apparent adjusted time is considered verified. Adjusted time is 22.4.

(2) Example 2.

Round	Time	Spotting	Comment
1-----	21.8	G	Subtract 0.4.
2-----	21.4	A	Split the 0.4 time bracket.
3, 4-----	21.6	A, A	Add 0.2.
5-----	21.8	A	Mean height of burst reported is 25 meters. Apparent adjusted time is 21.8. Must be verified.
6-----	22.0	A	Fire another round.
7-----	22.0	G	Adjusted time is 21.9 (A, G at 21.8 and A, G at 22.0). If round 7 had been AIR, a new registration would have been required.

Section IV. MEAN-POINT-OF-IMPACT AND HIGH-BURST REGISTRATIONS

19-27. General

a. The opportunities to conduct registrations on clearly defined, accurately located registration points in the target area are limited. At night, the adjustment of fire on a registration point without some type of illumination is impossible. In desert, jungle, or arctic operations, clearly defined registration points normally are not available. Either of two alternate registration procedures may be used to overcome these limitations. These procedures are known as the mean-point-of-impact (MPI) registration and the high-burst (HB) registration. In an MPI or HB registration, the mean burst location of a group of rounds (normally six) fired with a single set of data is determined.

b. An HB registration offers distinct advantages over an MPI registration because a time

fuze is employed. Since airbursts are used, deflection, range, and fuze corrections may be determined simultaneously. An HB registration is easier to observe, especially at night, and corrections may be obtained for areas concealed from ground observation.

19-28. Selection of Point at Which to Register

a. The point at which a mean-point-of-impact registration is to be fired should be—

(1) Close to the center of the zone into which the unit is expected to fire.

(2) In a relatively level area, free of ravines and objects which might obscure bursts.

(3) In an area visible to the observers.

b. The point at which a high-burst registration is to be fired should be—

(1) Over the center of the zone into which the unit is expected to fire.

(2) High enough to be visible to the observers.

★(3) High enough that airbursts are assured (consideration must be given to height of burst probable error) but not so high that quadrant elevation and the vertical interval to the predicted burst point computed from the battery exceed the limitations stated on the reverse side of the appropriate GST. Exceeding these limitations introduces errors which are not acceptable. Fifty meters above the ground is usually a good height of burst.

19-29. Orientation of the Observers

a. Lines of known direction for the observers should be established on the ground. The observers must be furnished azimuth and vertical angles to the expected point of burst. The azimuths are usually determined graphically from the firing chart. The vertical angles normally are computed by using the C and D scales of the graphical site table.

b. A message to the observers prior to firing an MPI or HB registration contains a warning order, orientation data for each OP, a directive to observer 01 to measure and report vertical angles, and a directive to both observers to report when ready to observe. Since 01 is the control OP, vertical angles should be measured at 01.

Example: OBSERVE HIGH BURST. 01, DIRECTION 1065, VERTICAL ANGLE +10, MEASURE THE VERTICAL ANGLE. 02, DIRECTION 785, VERTICAL ANGLE +8. REPORT WHEN READY TO OBSERVE.

c. Observer procedures are discussed in paragraph 13-17 and 13-18.

19-30. Determination of Firing Data

a. The point at which the registration is to be fired is plotted on the firing charts. The horizontal control operator (HCO) determines and announces the chart range and deflection to the selected point.

b. The vertical control operator (VCO) determines the site to the selected point. The ver-

tical interval used in the determination of site for a high-burst registration is determined by subtracting the altitude of the gun from the sum of the altitude of the ground under the selected point and the desired height of burst above the ground.

c. The computer determines the fire commands based on the announced chart data. The method of fire is BASE PIECE or NUMBER (so-and-so) ONE ROUND, AT MY COMMAND. In well-trained units, the methods of fire may be changed to BASE PIECE (so many) ROUNDS AT (so many) SECONDS INTERVAL after the observers have oriented on the initial round. When the method of fire is BASE PIECE (so many) ROUNDS AT (so many) SECONDS INTERVAL, each observer must carefully identify the round to which each reading pertains.

d. Firing data are not changed during the registration unless a change is necessary to move the bursts to a point visible to the observers or to increase site if graze bursts occur in a high-burst registration. All rounds considered in an MPI or HB registration must have been fired with the same data.

19-31. Procedure During Firing of a High-Burst or Mean-Point-of-Impact Registration

a. When the battery has reported READY and the observers have reported READY TO OBSERVE, the S3 commands FIRE. The first round is used to orient the observers and normally is not considered as one of the usable rounds.

b. If either of the observers cannot observe the initial round, firing data may be changed to move the burst until both observers can see the burst.

c. After the observers have located the burst, the registration is continued. One round at a time is fired until six usable rounds have been obtained. Each observer reports the direction to each burst, and the designated observer reports the vertical angle to each burst.

d. Any round which appears to be erratic is disregarded. In judging whether a round is er-

atic, the S3 must consider the locations of the observers with respect to the gun-target line and the size of the probable errors. Any round not disregarded as erratic or erroneously spotted by an observer is considered usable.

19-32. Determination of the Location of the Mean Point of Impact or High Burst

a. When six usable rounds have been fired, the azimuth from each OP and the vertical angles are averaged. The average azimuth is the azimuth from the OP to the mean burst location of the six usable rounds. The average vertical angle is the vertical angle to the mean burst location.

b. The following information is known and is used to determine the location of the MPI or HB: location of OP's, length of base (distance between OP's), azimuth from one OP to the other, azimuth from each OP to the mean point of impact or high burst, and vertical angle from one OP to the mean point of impact or high burst.

c. The methods by which the MPI or HB may be located, in order of accuracy, are—

(1) Computation of grid coordinates and altitude of the mean point of impact or high burst (FM 6-2).

(2) Computation of azimuth, distance, and vertical interval from one OP to the mean point of impact or high burst and then polar plotting from the observation post.

(3) Graphic intersection and computation of vertical interval from one OP to the mean point of impact or high burst.

19-33. Determination of Chart Data to the Mean Point of Impact or High Burst

a. After the mean point of impact or high burst is located and plotted, the HCO measures the deflection and range to the mean point of impact or high burst from the battery which fired the mission. The range and deflection measured are the chart range and chart deflection.

b. After the mean point of impact or high burst is located and plotted, the VCO computes

site by determining the vertical interval and dividing the vertical interval by the chart range (GST) for the appropriate charge. He determines the vertical interval by subtracting the altitude of the battery from the altitude of the mean point of impact or high burst.

★19-34. Determination of Adjusted Elevation and Adjusted Time

a. The quadrant elevation used to fire the six usable rounds in a mean-point-of-impact or high-burst registration is the adjusted quadrant elevation. The site (para 19-33b) is subtracted from the adjusted (fired) quadrant elevation to determine the adjusted elevation.

b. The fuze setting used to fire the six usable rounds in a high-burst registration is the adjusted time. When the determined vertical interval to the high-burst (para 19-33b) is small (100 meters or less) use the fuze setting corresponding to the adjusted elevation to determine the total fuze correction. However, when a large vertical interval (greater than 100 meters) is determined to the high-burst, the complementary angle of site should be added to the adjusted elevation to determine the total fuze correction. The procedure for determining the total fuze correction when the vertical interval is greater than 100 meters is as follows:

(1) Determine the angle of site and site to the reported mean location of the high-burst (GST).

(2) Determine the complementary angle of site (site minus angle of site).

(3) Determine the fuze setting for the adjusted elevation plus the complementary angle of site (GFT).

(4) Determine the total fuze correction by subtracting the fuze setting for the adjusted elevation plus complementary angle of site from the fuze setting used to fire the high-burst registration.

(5) Add the total fuze correction to the fuze setting for the adjusted elevation. At this value (adjusted fuze setting at the level point) construct the time gageline on the cursor of the GFT. The GFT setting now permits accurate transfer of time fires within small vertical intervals (100 meters or less). When firing fuze time and first round accuracy is required

for targets with large vertical intervals (greater than 100 meters) fuze settings should be determined by applying the total fuze correction to the fuze setting for the elevation plus complementary angle of site to the target. (See para 19-36, example problem 2).

19-35. Example Problem

★*a.* A 155-mm howitzer M109 battalion has just made a night occupation of position. Survey has been completed. In order to accurately fire a predawn preparation, the S3 decided to fire a high-burst registration (charge 5). After studying the map, the S3 decides to fire the high burst at grid intersection 6242 with a desired height of burst above the ground of 60 meters. The altitude at the grid intersection is 407 meters.

b. The survey officer furnished the following data:

		Altitude (meters)
Coordinates of Battery B.	5708538148	381
Coordinates of 01	6159939123	436
Coordinates of 02	6039639620	431
Distance 01 to 02	1,302 meters	
Azimuth 01 to 02	5,199 mils	

c. The HCO constructed a firing chart with 01, 02, and all batteries plotted. He measures the following azimuth and distances from 01 and 02 to the 6242 grid intersection:

(1) 01 to 6242—azimuth 141 mils, distance 2,900 meters.

(2) 02 to 6242—azimuth 604 mils, distance 2,870 meters.

d. The VCO computes the vertical angles from 01 and 02 to the desired location of the high burst.

(1) Desired altitude of HB is 467 meters (407 + 60).

(2) 01 vertical interval = +31 (467 - 436). Vertical angle = +11 mils (+31/2900, GST).

(3) 02 vertical interval = +36 (467 - 431). Vertical angle = +13 mils (+36/2870, GST).

e. The following message is sent to the observers:

OBSERVE HIGH BURST. 01, DIRECTION 141, VERTICAL ANGLE +11, MEASURE THE VERTICAL ANGLE. 02, DIRECTION 604, VERTICAL ANGLE +13, REPORT WHEN READY TO OBSERVE.

f. The HCO measures and announces the following chart data for Battery B: RANGE 6240, DEFLECTION 3177.

g. The VCO computes and announces the following site:

(1) Vertical interval = +86 (467 - 381).

(2) Site = +15 mils (+86/6240, GST, charge 5).

★*h.* The computer determines and sends to the battery the following fire command: BASE PIECE ADJUST, SHELL HE, LOT ZT, CHARGE 5, FUZE TIME, BASE PIECE ONE ROUND, AT MY COMMAND, DEFLECTION 3177, TIME 20.8, QUADRANT 327.

i. When the base piece and both observers report READY, firing is begun. As each round is observed, the observers report in numerical order; e.g., 01, DIRECTION (so much), VERTICAL ANGLE (so much); 02, DIRECTION (so much). The directions and vertical angles are recorded, and the next round is fired. When six usable rounds have been observed, the mission is ended. The following data was reported by 01 and 02 and recorded and averaged at the FDC:

Round number	01 direction	01 vertical angle	02 direction
*1	-----	-----	-----
2	110	+8	590
3	108	+8	588
4	111	+7	589
5	115	+7	588
*6	-----	-----	-----
7	107	+7	590
8	111	+7	590
Total	662	+44	3535
Average (6 rounds)	110	+7	589

*Rounds number 1 and 6 were considered erratic and were disregarded.

j. The location of the mean burst is then computed in the following manner (fig. 19-5) (DA Form 6-55, High-Burst (Mean-Point-of-Impact) Registration):

- (1) Compute distance from 01 to high burst—

Apex angle = 479 mils (589-110).
Angle at 02 = 1,410 mils (1999-589).

Using law of

$$\begin{aligned} \text{sines:} \quad & \frac{\text{dis 01 to HB}}{\sin 1410} = \frac{1302}{\sin 479} ; \\ & \frac{\text{dis 01 to HB}}{= \frac{1302 \times \sin 1410}{\sin 479}} \end{aligned}$$

$$\text{Log 1302} = 3.114611$$

$$\begin{aligned} + \log \sin \\ 1410 &= \frac{9.992400}{13.107011} \end{aligned}$$

$$- \log \sin 479 = 9.656209$$

$$\text{Log distance} = 3.450802$$

01 to HB

$$\text{Distance 01} = 2,823.6 \text{ meters to HB}$$

- (2) Compute coordinates and altitude of high-burst location.

$$dE = D \sin B$$

$$\text{Log } D = 3.450802$$

$$\text{Log } \sin 110 = 9.032548$$

$$\text{Log } dE = 2.483350$$

$$dE = +304$$

$$01 = 61599$$

$$\frac{61903}{41930}$$

$$dN = D \cos B$$

$$\text{Log } D = 3.450802$$

$$\text{Log } \cos 110 = 9.997462$$

$$\text{Log } dN = 3.448264$$

$$dN = +2807$$

$$39123$$

$$41930$$

$$dH = D \tan \text{vertical angle}$$

$$\text{Log } D = 3.450802$$

$$\text{Log } \tan 7 = 7.837105$$

$$\text{Log } dH = 1.287907$$

$$dH = +19$$

$$436$$

$$455$$

Grid coordinates of high burst are 6190341930; altitude is 455.

k. The chart operators plot the high-burst location and determine the following chart data:

- (1) HCO: range 6130; deflection 3178.

- (2) VCO: vertical interval = +74 (455-

381). Site = +13 mils (+74/6130, charge 5).

l. The following is a tabulation of the essential information derived from this registration:

Chart data	Adjusted (fired) data
Range (6,130 meters)	QE 327 mils
Deflection (3,178 mils)	Elevation 314 (327 — (+13))
Site (+13 mils)	Deflection 3,177 mils
	Time 20.8

Note. Site is always determined using chart range.

★19-36. Radar Registrations

a. *General.* The AN/MPQ-4A and AN/MPQ-10A radar systems were designed to be employed in the countermortar and counterbattery role. However, the capabilities of these radars are such that they can profitably be employed in observing high-burst and mean point-of-impact registrations. When proper techniques and procedures are employed, the accuracy of registration corrections obtained by the radar observed method is comparable to that of corrections obtained by other methods.

b. *Employment.* Employment and position requirements for the radar set depend upon the tactical mission assigned the radar section and certain technical and tactical factors which influence the operation of this equipment. The complete suitability of a radar site can be determined only by the accomplishment of the assigned mission from this site. The radar position should as a minimum be located adjacent to one of the firing batteries. Such a location simplifies communications facilities, survey and logistics, and enables the section to take advantage of an existing defensive perimeter. When selecting the optimum radar site, consideration for the range capabilities of the radar should also be taken into account in order that as many batteries as possible may take advantage of the radar's registration capabilities. This should be done without degradation of the radar's countermortar or counterbattery role. The radar should be placed in defilade to afford personnel and equipment protection from hostile fire and reduce the effects of electronic countermeasures.

HIGH BURST (MEAN POINT OF IMPACT) REGISTRATION											
COMPUTATION OF HB (MPI) LOCATION											
Message to Observers OBSERVE HIGH BURST, O1, DIRECTION 141, VERTICAL ANGLE +11, MEASURE THE VERTICAL ANGLE. O2, DIRECTION 604, VERTICAL ANGLE +13. REPORT WHEN READY TO OBSERVE					Dis O1 → O2 1302M	Az O1 → O2 5199 + 3200 Az O2 → O1 1999					
Date Fired	Chg	5	DI	3177	FS	20.8	QE	327			
Observer Readings				Interior Angles							
Rd No	O1 Az	VA	O2 Az	O1 on Left			O1 on Right				
1	96	10	572	Az O1 → HB (MPI)			Az O2 → HB (MPI)				
2	110	+8	590	+6400 if necessary			+6400 if necessary				
3	108	+8	588	Total			Total				
4	111	+7	589	-Az O2 → HB (MPI)			-Az O1 → HB (MPI)				
5	115	+7	588	APEX $\angle$			APEX $\angle$				
6	96	10	570	Az O2 → HB (MPI)			Az O2 → O1				
7	107	+7	590	+6400 if necessary			+6400 if necessary				
8	111	+7	590	Total			Total				
9				-Az O2 → O1			-Az O2 → HB (MPI)				
10				$\angle$ at O2			$\angle$ at O2				
662 +44 3535 110 +7 589				Total Average			Bearing = Az 6400 - Az dE - dN +				
Distance O1 HB (MPI)				Bearing = Az 3200 - Az			Az O1 → HB (MPI) - Bearing 110 Bearing N 110 E				
Log base O1 → O2				3 114 611							
+ Log sin $\angle$ at O2				9 992 400							
Sum				13 107 011							
- Log sin Apex Angle				9 666 209							
diff = Log dist O1 HB (MPI)				3 450 802							
Dist O1 → HB (MPI)				2823.6M							
Log of dE, dN, and dH											
Log dist O1 → HB (MPI)			3 450 802			Log dist O1 → HB (MPI)			3 450 802		
Log sin Bearing			9 032 548			Log cos Bearing			9 997 462		
Sum = Log dE			2 483 350			Sum = Log dN			3 448 264		
Log tan Vert $\angle$			7 837 105			Log dH			1 287 907		
Coordinates of O1			E 61 599			N 39 123			H 436		
			$\oplus$ dE 304			$\oplus$ dN 2807			$\oplus$ dH 19		
Location of HB (MPI)			E 61 903			N 41 930			H 455		
COMPUTATION OF GFT SETTING											
All HB (MPI)	455	QE fired	327	Chart data to HB (MPI) location				DI corr			
- All Btry	381	- Site VI/HB (MPI) Rq	+ 13	Deflection 3178 m Range 6130 m							
VI	$\oplus$ 74	Adj Elev	314	GFT = 3 Charge 5 Lot 27 Range 6130 Elevation 314 Time 26.8				R 1			

DA FORM 6-55
1 NOV 67

Figure 19-5. Computation of High Burst Registration.

c. Advantages and Disadvantages. A radar registration, when compared to other methods of conducting a registration, has certain advantages and disadvantages. Most of the advantages are due to a reduction in the time required to prepare to observe the registration. Less survey is required for radar than is required for sound, flash, or target area bases, since only the radar and the registering piece must be on a common grid. Fewer communications facilities are required since only the radar, the FDC, and the registering battery need communicate. A radar observed mean-point-of-impact registration can be conducted only when the round can be visually observed from radar in order to maintain accuracies within acceptable limits. High-angle registrations may be conducted using radar MPI techniques. Radar registrations can provide polar plot data from the radar to the mean location of six usable rounds to the high-burst (MPI) or give coordinates and altitude quickly. Also, the direction, distance, and vertical angle from the radar for each individual round may be reported. Ranges from the radar to the high-burst (MPI) are slant ranges. For plotting and computational purposes the horizontal error introduced is insignificant and the radar range is considered to be horizontal range.

d. Selection of Orientation Point. Some coordination and mutual understanding must exist between the FDC and radar personnel in the choice of a high-burst (MPI) orientation point. The FDC requires that the quadrant elevation and the vertical interval to the predicted burst point computed from the battery center do not exceed the limitations stated on the reverse of the appropriate GST. Exceeding these limitations introduces errors which are not acceptable. The FDC designates the location of the selected point to the radar. The predicted altitude of the selected point must be coordinated between the FDC and the radar section based upon the sighting requirements of the radar. If either the sighting requirements of the radar or the limitations of the appropriate GST are exceeded, the FDC must select another point or cancel the registration. The procedure for coordinating the predicted altitude of the se-

lected point for a high-burst or MPI registration is as follows:

(1) For a high-burst registration, the selected point must be optically visible from the radar. In order to optically observe elevations below as well as above the selected point, the pointing elevation of the radar must be 10 mils above the radar screening crest. The elevation to the screening crest is measured from the radar along the azimuth to the selected burst point by sighting through the optical telescope. The pointing elevation of the radar should not, if possible, exceed 50 mils. The radar section computes the altitude of the predicted burst point based upon the radar range and the pointing elevation. This altitude is reported to the FDC for computation of site for the initial quadrant to be fired.

(2) For a radar MPI registration only electrical line of sight is necessary. However, the pointing elevation to the selected point is determined in the same manner as for the high-burst registration to insure electrical beam clearance. A characteristic of the radar MPI registration is that the rounds normally cannot be observed at impact because the radar is usually sited behind a mask. Therefore, it is necessary that the radar observe the artillery rounds at some place in space where all rounds pass through the radar beam from which radar personnel compute the chart location of the six usable rounds (see fig. 19-6). The FDC will utilize the ground site determined from the map inspected altitude of the orientation point to compute the quadrant to be fired.

e. Message to the Observer. If radar registrations are to be conducted efficiently and rapidly, certain data must be furnished to the radar section by the fire direction center. To provide these data, the FDC prepares a message to the observer. This is a standard message which contains from four to six elements; the number depends on the type of registration to be fired (HB or MPI). These are listed below in their proper sequence and content under various conditions.

(1) *Warning order.* This element must always be included. It consists of the order OBSERVE HIGH BURST (MPI). This informs

the radar section of the type of registration to be fired and notifies it to begin preparations immediately.

(2) *Unit to fire.* This element may be eliminated by SOP when it is unnecessary for the radar section to contact the battery to fire or to know the battery location. It consists of the word FOR, followed by the call sign or code name of the unit to fire.

(3) *Grid.* This element must always be included. It specifies the military grid reference of the orientation point to the nearest 10 meters.

(4) *Minimum acceptable altitude.* This element consists of the phrase, MINIMUM ALTITUDE, followed by the altitude, in meters, below which the orientation point should not be selected. This altitude should be high enough to insure airbursts when conducting a high burst registration. 50 meters is usually a good height of burst but in no case should be less than 2 PE_H above the selected point. This element is omitted for mean-point-of-impact registrations.

(5) *Altitude Report.* This element consists of the command, REPORT ALTITUDE. This requires the radar section to determine the altitude of the announced high burst (orientation) point based upon the range and elevation of the radar to that point and to report this value to the FDC as soon as possible. The FDC utilizes this predicted altitude to compute site for the initial quadrant to be fired for the high burst registration. If the predicted altitude is below the minimum acceptable altitude, the minimum acceptable altitude is then reported to the FDC and the radar is oriented to that point in space. If the predicted altitude causes the FDC to exceed the limitations of the GST, the FDC must either move the orientation point or cancel the mission. This element is omitted for radar MPI registrations.

(6) *Report Order.* This element consists of the order REPORT WHEN READY TO OBSERVE. It requires the radar section to inform the FDC when the section is ready to observe the registration. When utilizing the AN/MPQ-10A radar system for MPI registrations this element must be preceded by the weapon caliber, charge, and quadrant to be

fired. This is necessary for further orientation of the AN/MPQ-10A radar set.

f. Conduct of Radar Registrations. The determination of initial firing data, procedures during firing and the determination of chart and adjusted data are identical to standard high-burst and MPI registrations (para 19-30 through 19-34) except as noted in the preceding paragraphs and the following example problems.

Example problem 1.

a. A 155-mm howitzer M109 battalion has just made a night occupation of position. Position area survey has been completed. There are no surveyed OP's. An AN/MPQ-4A radar section is located in a nearby direct support battalion perimeter. In order to accurately fire unobserved fires from this new position, the S3 decides to have Battery B fire a radar high-burst registration using charge 5. Upon inspection of the map the S3 decides to fire the high-burst at grid intersection 6237 with a desired height of burst of 50 meters. The map inspected altitude at grid intersection is 376 meters.

b. From the firing chart constructed by the HCO the following data to the 6237 grid intersection are measured and announced.

(1) BRAVO RANGE 6420

(2) DEFLECTION 3237

c. The VCO computes the minimum acceptable altitude to be sent to the radar to be 426 meters (376 + 50).

d. Message to Observer:

OBSERVE HIGH BURST FOR LOUD
THUNDER 18, GRID 62003700,
MINIMUM ALTITUDE
426, REPORT ALTITUDE, REPORT WHEN
READY TO OBSERVE.

e. Altitude report from radar: ALTITUDE 456

f. The VCO computes and announces the following site:

(1) Battery B—Altitude 352

(2) VI = +104 (456—352)

(3) Site = +18 (+104/6420 GST)

g. The computer determines and sends to the battery the following fire commands:

BASE PIECE ADJUST, SHELL HE; LOT
XZ, CHARGE 5, FUZE TIME, BASE
PIECE ONE ROUND AT MY
COMMAND, DEFLECTION 3287,
TIME 21.6, QUADRANT 342

Note. Computed data cannot exceed previously stated GST limitations.

h. When the radar reports AT MY COMMAND, REQUEST SPLASH, READY TO OBSERVE, and the base piece reports READY, firing is begun. When the radar section receives SHOT from the FDC it is prepared to reorient the antenna if the burst is greater than 10 mils from the scope/beam center in either azimuth or elevation. If such a case occurs the first round should be discounted as an orientation round. As each round is fired the radar will report OBSERVED or UNOBSERVED. The case may arise when an OBSERVED is reported and followed by REQUEST SITE INCREASE early in the registration because the burst is occurring too low. The S3 will have the computer increase the quadrant the amount of mils necessary to raise the burst approximately 2 PE_H using the 100/R factor.

(1) The computer determines the PE_H from the supplementary data table by interpolation using the range to the orientation point expressed to the nearest 100 meters.

$PE_H = 17$ (FT 155-AH-2 Table G, Charge 5 GB)

$2 PE_H = 34$ (30)

$100/R = 16$

Site increase = $+5$ mils ($\frac{30 \times 16}{100}$)

(2) The quadrant previously fired is increased by 5 mils and the computer now announces QUADRANT 347 (342 + 5).

(3) If the bursts continue to be either too low or too high to be visible within 10 mils of the center of the radar telescope, a further increase or decrease of the quadrant in smaller increments may be deemed necessary. This precludes further orientation of the radar and will permit the radar section to provide optimum data to the mean location of the six usable rounds.

i. When six usable rounds have been observed by the radar, the mission is ended by the radar section with the report END OF MISSION.

j. The location of the mean burst is computed by the radar section and is reported to the FDC in one of the three previously stated methods. The grid coordinates and altitude is the most rapid and easiest to report since the radar location need not be plotted on the firing chart.

REPORT FROM RADAR

HIGH BURST, OBSERVED 2315 HOURS,
GRID 62403688, ALTITUDE 438.

k. The chart operators plot the announced high burst location and determine the following data:

(1) HCO: RANGE 6310, DEFLECTION 3282.

(2) VCO: SITE +15 (+86/6310).

Note. Vertical interval does not exceed 100 meters and standard procedures are followed.

The following is a tabulation of the essential information derived from this registration:

Chart Data		Adjusted Data	
Range	6310	QE	347
Deflection	3282	Elevation	332
Site	+15	Deflection	3287
		Time	21.6

GFT setting; GFT B; Charge 5, Lot XZ, Range 6310, Elevation 332, Time 21.6

Total Deflection Correction: L5

Example problem 2.

The following problem illustrates the conduct of a high-burst registration and the determination of corrections when the vertical interval from the battery to the reported altitude of the radar high burst exceeds 100 meters.

a. The S3 decides to have Battery A (155-mm howitzer, M109) fire a radar high burst at grid intersection 6337 with a desired height of burst of 50 meters. The map inspected altitude of the grid intersection is 370 meters.

b. The following data are measured and announced by the HCO:

- (1) ALFA RANGE 6530
- (2) DEFLECTION 3198

c. The VCO computes the minimum acceptable altitude to be sent to the radar.

MINIMUM ALTITUDE 420 (370 + 50)

d. Message to Observer: OBSERVE HIGH BURST FOR LOUD THUNDER 18, GRID 63003700, MINIMUM ALTITUDE 420, REPORT ALTITUDE, REPORT WHEN READY TO OBSERVE.

e. Altitude report from radar: ALTITUDE 538.

f. VCO computes and announces the following site:

(1) Battery Altitude 355

(2) VI = +183 (538 - 355)

(3) Site = +32 (+183/6530 charge 5 GST)

g. The computer determines and sends the following fire commands to the battery: BASE PIECE ADJUST, SHELL HE, LOT QN, CHARGE 5, FUZE TIME, BASE PIECE ONE ROUND AT MY COMMAND, DEFLECTION 3198, TIME 22.0, QUADRANT 363.

(1) Complementary angle of site

(2) Adjusted elevation

(3) Adjusted elevation plus complementary angle of site

(4) Fuze setting for adjusted elevation plus complementary angle of site

(5) Total fuze correction

(6) Fuze setting for adjusted elevation

(7) Adjusted fuze setting at the level point

= + 3 (+30 - (+ 27))

= 333 (363 - (+ 30))

= 336 (333 + 3)

= 22.3

= - 0.3 (22.0 - 22.3)

= 22.1

= 21.8 (22.1 + (-0.3))

k. The following is a tabulation of the essential information derived from this registration:

Chart data		Adjusted data	
Range	6340	QE	363
Deflection	3191	Elevation	333
Site	+30	Deflection	3198
		Time	21.8

GFT setting: GFT A: Charge 5, LOT QN, Range 6340, Elevation 333, Time 21.8

Total Deflection correction: L7

Note. When firing time fuze with first round accuracy on targets with vertical intervals exceeding 100 meters, the constructed time gage line should not be used and the total fuze

Note. Computed data cannot exceed previously stated GST limitations.

h. Six usable rounds are observed by the radar and the mission is ended with the report END OF MISSION.

REPORT FROM RADAR

HIGH BURST OBSERVED 1835 HOURS,
GRID 61063682, ALTITUDE 522.

i. The chart operators plot the announced high burst location and determine the following data:

(1) HCO: RANGE 6340

DEFLECTION 3191

(2) VCO: VI + 167* (522-355)

SITE = +30 (167/6340 GST

Charge 5)

ANGLE OF SITE = +27

(+ 167/6340 C and D scales

GST).

*Note. Vertical interval exceeds 100 meters and consideration of the complementary angle of site in the determination of the total fuze correction should be taken into account.

j. The computer determines the total fuze correction and the adjusted fuze setting at the level point (GFT).

correction should be added to the fuze setting for the elevation plus the complementary angle of site to the target.

Example Problem 3.

a. A 155-mm howitzer M109 battery has just made an occupation of position during an intense fog. Survey is complete, but due to the fog the established OP's have very limited visibility. An AN/MPQ-4A radar section is located in an adjacent battery's perimeter. The battery fire direction center officer decides to fire a mean-point-of-impact registration at grid intersection 6336 using charge 4. The map inspected altitude at this grid intersection is 382 meters.

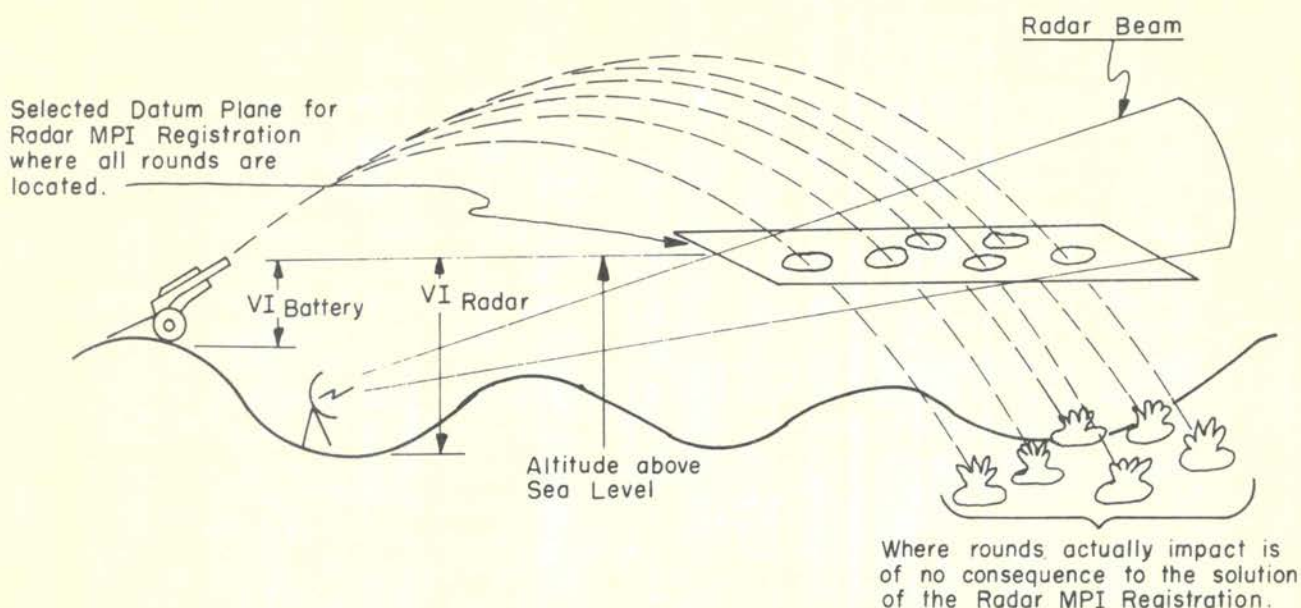


Figure 19-6. Theoretical MPI selected datum plane.

b. The HCO measures and announces the following data to the grid intersection:

- (1) CHARLIE RANGE 5180
- (2) DEFLECTION 3047

c. Message to Observer: OBSERVE MPI FOR LOUD THUNDER 69. GRID 63003600, REPORT WHEN READY TO OBSERVE.

d. The VCO computes and announces the following site:

- (1) Battery C — Altitude 348.
- (2) VI = +34 (382 — 348)
- (3) Site = +8 (+34/5180 GST).

e. The computer determines and sends to the battery the following fire commands: BASE PIECE ADJUST, SHELL HE, LOT LS, CHARGE 4, FUZE QUICK, BASE PIECE ONE ROUND AT MY COMMAND, DEFLECTION 3047, QUADRANT 328.

f. When six usable rounds are observed by the radar, the mission is ended with the report END OF MISSION. The location of the MPI in the

selected datum plane is computed by the radar section and is reported to the FDC.

REPORT FROM RADAR

MPI OBSERVED 0945 HOURS, GRID
62933566, ALTITUDE 434.

g. The chart operators plot the announced location and determine the following chart data:

- (1) HCO: RANGE 4830
DEFLECTION 3053
- (2) VCO: Vertical interval + 86
(434 — 348), Site + 20
(+ 86/4830 GST)

h. The following is a tabulation of the essential information derived from this registration:

Chart data		Adjusted Data	
Range	4830	QE	328
Deflection	3053	Elevation	308
Site	+20	Deflection	★ 3047

GFT C: Charge 4, Lot LS, Range
4830, Elevation 308.

Total deflection correction: R6

Section V. REGISTRATION WITH MORE THAN ONE AMMUNITION LOT

19-37. General

Though the ballistic characteristics of propellants vary from one lot to another, the ballistic differences between projectile lots are negligible. Correction for difference in weight of projectile can be computed. Because of this, registration with the same propellant lot and different projectile lots provides no appreciable gain in accuracy and is not necessary. Only when a large quantity of propellant from a particular lot is present should a registration be made with the lot. The procedure described in this section applies when more than one large quantity propellant lot is on hand.

19-38. Procedure for Registration With More Than One Lot

a. As soon as the adjusted quadrant elevation has been determined for the first lot, the registration is begun with the second lot. The observer should be notified, and he continues to spot as in fire for effect.

b. The first round of the new lot is fired with the adjusted quadrant elevation of the first lot. As soon as a definite FDC range spotting is obtained, the quadrant elevation is changed 1 even fork in the appropriate direction. (If the

value of the fork is an odd number, the quadrant elevation is changed by the next higher even value. This procedure facilitates splitting the bracket, when it is established. The true value of the fork is used to compute the adjusted elevation.) This procedure is continued until an even fork bracket is established. The fork bracket is split. Procedures in paragraphs 19-13 and 19-14 are followed as in the registration with the first lot of ammunition.

c. The correct deflection established for one lot is used for all lots because deflection is not affected appreciably by the ballistic differences between lots. Therefore, if the correct deflection has not been established for the first lot by the time the adjusted elevation is determined, the registration with the second lot is begun and the deflection adjustment is continued during the second registration until the correct deflection is established.

d. The use of different fuze lots with the same propellant lot does not require separate impact registrations.

e. When one lot of time fuzes is to be used with more than one propellant lot, the total fuze correction determined for that fuze lot by registration with one propellant lot normally is valid for use with the other propellant lots.

CHAPTER 20

DETERMINATION AND APPLICATION OF REGISTRATION CORRECTIONS

Section I. INTRODUCTION

20-1. Determination of Registration Corrections

Registration corrections consist of range, fuze, and deflection corrections. These corrections are determined by comparing "should hit" firing data to the "did hit" firing data.

20-2. Application of Registration Corrections

When properly applied, registration corrections permit transfer of fires, i.e., firing for effect upon an accurately located target, without an adjustment. Registration corrections also facilitate accurate plotting of targets located by the adjustment of fire.

Section II. REGISTRATION RANGE CORRECTIONS

20-3. Computation of Total Range Correction

a. If standard conditions exist, the elevation to be fired to achieve the chart range is the elevation listed in the firing table for that range. When nonstandard conditions exist, the range achieved by firing a particular elevation differs from the range indicated in the firing tables by an amount equal to the cumulative effect of all nonstandard conditions.

b. The chart range for a registration is measured from the battery center to the registration point, mean point of impact, or high burst. If the registering piece is in front of or behind the battery center, the measured chart range is not the range achieved. The adjusted elevation from a registration is the elevation which achieved the range from the registering piece to the registration point. This is the GFT setting range, which is determined by modifying the chart range by the amount the base piece is in front of or behind the battery center.

★*Example:* A 155-mm howitzer M109 battery has registered with charge 5. Chart range is 5,000 meters. The adjusted elevation is 245. The base piece is 30 meters behind the battery

center (fig. 20-1). The range actually achieved (GFT range) is 5,030 meters ($5000 + 30$).

c. The adjusted elevation is the sum of the elevation listed in the firing tables for the GFT range and the elevation correction necessary to compensate for the cumulative effect of all nonstandard conditions. The total range correction is the correction in meters corresponding to the elevation correction. The total range correction is determined in the following manner:

- (1) Determine, from the firing tables, the range corresponding to the adjusted elevation.
- (2) Subtract the achieved range from the range corresponding to the adjusted elevation. The result is the total range correction.

Example: In the example in *b* above, the range corresponding to elevation 245 (GFT) is 5170, and the total range correction is +140 ($5170 - 5030 = +140$).

20-4. Total Fuze Correction

The total fuze correction is determined by subtracting the fuze setting listed in the firing tables corresponding to the adjusted elevation

(or elevation plus complementary angle of site) from the adjusted time.

★*Example:* Continuing the example in paragraph 20-3b, the adjusted time obtained was 16.3. The fuze setting corresponding to the adjusted elevation of 245 is 16.6. The total fuze correction is -0.3 ($16.3 - 16.6$).

20-5. Application of Total Range and Total Fuze Corrections

Use of total range and total fuze corrections as determined in paragraphs 20-3 and 20-4 is covered in chapter 21.

★20-6. Transfer Limits—Range

Registration range and fuze corrections are valid within the following transfer limits:

a. When the one plot GFT setting is used, transfer limits are between the red numbered elevations for the charge.

b. When the GFT setting is constructed from two or more plot points, it may be used for the full range limits of the GFT.

★20-7. GFT Settings

a. *One-Plot GFT Setting.* Known corrections from one registration (or met plus VE computation) are portrayed graphically on the GFT in the form of a one-plot GFT setting.

(1) For the one-plot GFT setting, the registration point (met checkpoint) must be selected so that the range to the registration point (met checkpoint) falls between the red numbered elevations on the elevation scale. Transfers may be made to all elevations within the red numbered elevations. The elements of the GFT setting are always expressed and recorded in the following sequence:

(a) Unit that registered.

(b) Charge.

(c) Ammunition lot.

(d) GFT setting range (chart range modified by base piece displacement) to the nearest 10 meters.

(e) Adjusted elevation.

(f) Adjusted time.

Example: GFT B: Charge 5, Lot XY,

Range 5920, Elevation 305, Time 19.9.

(2) The one plot GFT setting is placed on the GFT in the following manner:

(a) Place the hairline over the GFT setting range.

(b) Place a black dot on the cursor over the adjusted elevation.

(c) Place a red dot on the cursor over the adjusted time.

(d) Slide the cursor so that the black dot is over the black dashed line (RG K line) at the right end of the scale.

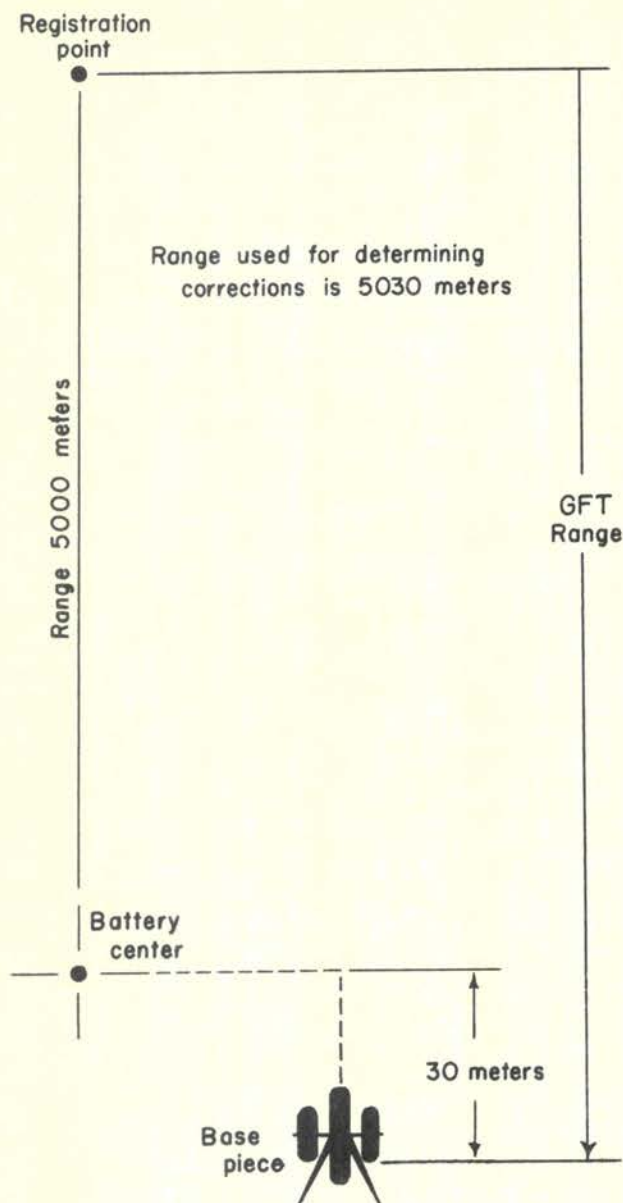
(e) Construct the elevation gageline by drawing on the cursor a fine black line over the dot at the same angle as the dashed line. The elevation gageline should extend from the top to the bottom of the cursor and may be labeled EL.

(f) Slide the cursor so that the red dot is over the black dashed line (FZ K line) at the left end of the rule.

(g) Construct the time gageline by drawing on the cursor a fine red line over the red dot at the same angle as the dashed line. The time gageline should extend from the top to the bottom of the cursor and may be labeled TI.

(3) The GFT setting determined from the registration is used to determine data for firing on a target as follows: Assume that the chart range to the target is 7,100 meters. Using the GFT setting in the example in (1) above, place the hairline over 7100 on the range scale. Read the elevation (392) under the elevation gageline; read 100/R (14 mils) under the hairline; read fork (5 mils) and drift (7 mils) under a visually simulated line parallel to the hairline and through the intersection of the elevation gageline and the elevation scale; read fuze setting (25.0) under the time gageline; read the change to fuze setting (FS) for a 10-meter change in height of burst under a visually simulated line parallel to the hairline and through the intersection of the time gageline and the fuze setting scale (①, fig. 20-2).

b. *Two Plot GFT Setting.* When data from two registrations, two met plus VE computations, or a combination thereof are known a



★ Figure 20-1. Base piece displacement correction-range.

more accurate GFT setting can be achieved by constructing range K and fuze K lines determined from two plot points. When a GFT setting is constructed from two plot points, it may be used for the full range of the GFT without regard to range transfer limits.

(1) The GFT setting with two elevation plot points and two time plot points is placed on the GFT in the following manner:

(a) Determine corrections in the lower third and in the upper third of the ranges of the GFT for the charge.

(b) Place the hairline over the GFT setting range to one of the registration points or met check points.

(c) Place a black dot on the cursor over the adjusted elevation and a red dot over the adjusted time.

(d) Repeat (b) and (c) above for the other registration point or met checkpoint.

(e) Construct the elevation gageline by drawing on the cursor a fine black line connecting the two black elevation dots. The elevation gageline should extend from the top to the bottom of the cursor and may be labeled EL.

(f) Construct the time gageline by drawing on the cursor a fine red line connecting the two red dots. The time gageline should extend from the top to the bottom of the cursor and may be labeled TI.

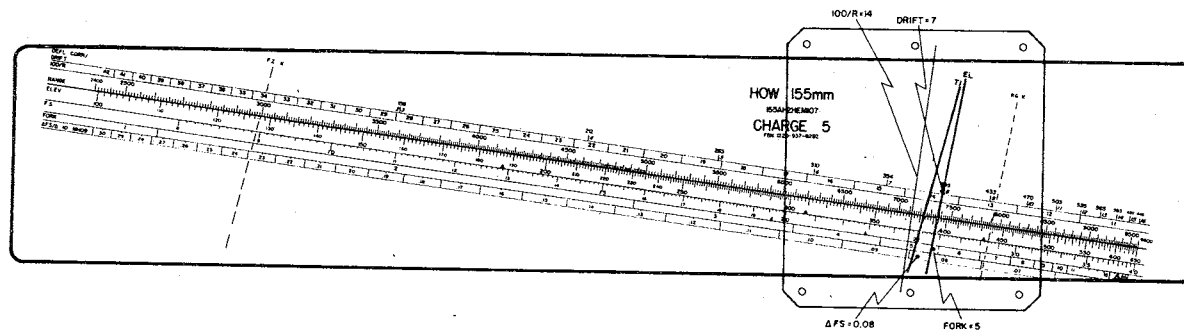
(2) Data from the two plot GFT setting gageline are read in the same manner as for the one-plot GFT setting (③, fig. 20-2).

c. *Multiple-Plot GFT Setting.* If the situation permits, an even more accurate GFT setting can be constructed by determining corrections to three or more points and drawing the elevation and time gageline by connecting the dots and extending the ends of these lines. As with the two-plot GFT setting, this eliminates range transfer limits and permits the use of the full range of the GFT.

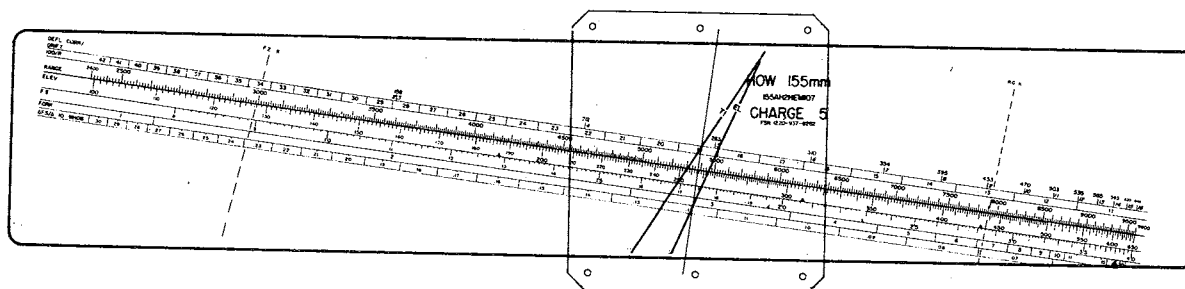
(1) The multiple plot GFT setting is constructed as follows: Assume that the gun direction computer M18 (FADAC) is available and the GFT is available and the GFT is being used as a backup system. The FADAC operator has obtained the following chart ranges and corresponding adjusted elevations and adjusted times:

Range	Elevation	Time
2900	120	8.6
4300	185	13.1
5700	255	17.8
7100	330	22.6
8500	414	27.8

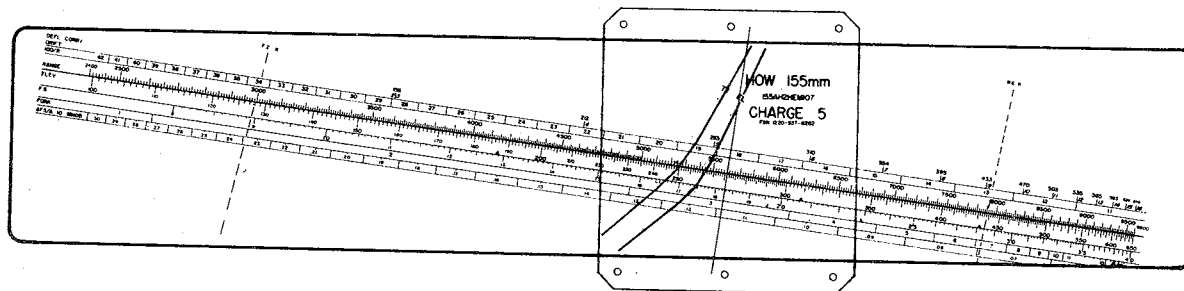
(a) Move the hairline over each chart range and place a black dot on the cursor over



★Figure 20-2.1 One plot GFT setting.



★Figure 20-2.2 Two plot GFT setting.



★Figure 20-2.3 Multiple plot GFT Setting.

each corresponding elevation and a red dot over each corresponding time.

(b) Construct the gagelines on the cursor by drawing a fine black line through each black dot and a red line through each red dot. (Use a series of straight lines.) The resulting elevation and time gagelines are more accurate than those of either the one- or two-plot GFT settings and can be used to transfer to all ranges on the GFT.

Figure 20-3. Rescinded

Figure 20-4. Rescinded

★20-8. Selection of GFT Setting

a. When only one battery of a battalion has registered, the GFT setting of that battery will be used by nonregistering batteries of the same caliber. Differences in shooting strength between the base pieces, if known, must be compensated for. If the batteries are widely separated in range or direction of fire to the registration point, the common GFT setting will not be accurately applicable to the nonregistering

batteries. However, in the absence of other data, this registration data is the best available. It is desirable, therefore, that the center battery conduct the registration, unless it is greatly echeloned in range from the flank batteries. In this case, the battery nearest the mean range to the registration point should conduct the registration.

b. If all batteries have registered with the same charge and this charge is to be used in a mission, each computer uses the GFT setting established by the registration of his battery.

20-9. GFT Settings for More Than One Lot

If the same charge has been used for registration with more than one lot of ammunition, two GFT settings may be placed on the cursor. The gagelines may be marked with the lot designation or color coded according to lot. Additional GFT settings are always recorded but are placed on the cursor only when used.

Section III. REGISTRATION DEFLECTION CORRECTIONS

20-10. Adjusted Deflection

The correct deflection derived from a registration or the fired deflection in a mean-point-of-impact or high-burst registration is the adjusted deflection only if the base piece is not displaced right or left from the battery center. If the base piece is displaced laterally from the battery center, the correct deflection must be modified to what the correct deflection would have been if the base piece had been over the battery center. The amount of the correction to be applied to the correct deflection is determined by dividing the amount of the lateral displacement in meters by the GFT range in thousands of meters (to the nearest 100 meters). If the base piece is to the right (left) of the battery center, the displacement correction is to the right (left).

Example: Battery B has registered on the registration point. The correct deflection determined was 3,252 mils. The GFT range is 5,030 meters. The base piece is 20 meters to the right of the battery center (fig. 20-5). The correc-

tion for base piece displacement is right 4 mils (20/5.0). The adjusted deflection is 3,248 mils (3252 + R4).

20-11. Total Deflection Correction

The total deflection correction is the correction that must be applied to the chart deflection to a target in order to determine a deflection that will hit the target. The adjusted deflection determined from a registration is the deflection which placed the mean burst center of rounds from all pieces in the battery at the registration point or the mean-point-of-impact or high-burst location. The deflection correction for the registration point (mean-point-of-impact or high-burst location) is determined by subtracting the chart deflection from the adjusted deflection. If the adjusted deflection is greater (less) than the chart deflection, the correction is left (right). For example, a registration has been completed on registration point 1. The adjusted deflection is 3248. The chart deflection to registration point 1 is meas-

ured as 3,256 mils. The total deflection correction for registration point 1 is right 8 (3248-3256 = R8).

★20-12. Deflection Correction Scale

a. The total deflection correction determined to a point is applicable only for the adjusted elevation to that point. As the elevation is changed, the resultant drift of the projectile will change correspondingly.

b. Drift is the departure of the projectile from a standard direction because of the combined action of air resistance, projectile spin, and gravity. Since all U.S. cannons impart a right-hand spin to the projectile, the drift is always to the right. Drift is a function of time of flight, and time of flight is a function of elevation plus complementary angle of site. For practical purposes, drift is considered a function of elevation.

c. As the elevation is increased, the projectile will drift further to the right; therefore, a left correction (the difference between the drift which will occur at the adjusted elevation and the drift which will occur at the elevation to be fired) must be applied. As the elevation is decreased below the adjusted elevation, drift will be less; therefore, a right correction must be applied.

d. For convenience, a deflection correction scale is constructed from which the required total deflection correction for any elevation within transfer limits may be determined by inspection. The deflection correction scale is normally constructed on the GFT; however, it may also be constructed in card form.

e. A separate deflection correction scale is constructed for each battery that has registered. When only one battery has registered, the deflection correction scale based on the GFT setting of the registering battery is used by all batteries of the same caliber.

★20-13. Construction of the Deflection Correction Scale

a. Normally, the deflection correction scale is constructed directly on the GFT by the computer; the procedure will differ depending on

whether it is based on a one-plot, two-plot, or multiple-plot GFT setting.

(1) One-plot GFT Setting.

(a) Range transfer limits for the one-plot GFT setting include the elevations printed in red on the elevation scale of the GFT.

(b) The total deflection correction determined from the registration is entered in the drift block that brackets the adjusted elevation. The elevations at which drift changes are printed in red on each drift change line.

(c) Since drift increases as the elevation increases, the total deflection corrections will change in increments of left 1 mil at each greater elevation where drift changes. Conversely, as the elevation decreases, the total deflection corrections will change in increments of right 1 mil. The total deflection corrections are recorded on the scale in each drift block.

Example: Assume that a registration was conducted with charge 5, that the adjusted elevation was 330, and that the total deflection correction was L8. The deflection correction scale is constructed on the GFT as follows:

200	212	263	310	354	395	433	470	500
			(330)					
L5	L6	L7	L8	L9	L10	L11	L12	

(d) To determine the total deflection correction at any elevation within transfer limits, place the hairline over the chart range and read the total deflection correction in the drift block corresponding to the elevation to be fired (fig. 20-6).

(2) *Two-Plot GFT Setting.* Where two total deflection corrections are determined from two registrations, two met plus VE computations, or a combination of the two determined for the same general direction (within 200 mils), the deflection correction scale is valid for the full range of the charge and is constructed as follows:

(a) Each total deflection correction is used as the basis for constructing the deflection correction scale halfway toward the other and may result in overlapping total deflection corrections or gaps between total deflection corrections.

1. When overlapping total deflection

corrections exceed 2 mils, a graphical solution is obtained. For example, assume that the following adjusted elevations and corresponding total deflection corrections were determined from two registrations, using charge 5: Elevation 190: total deflection correction R4. Elevation 438: total deflection correction L6. The initial deflection correction scale is constructed as follows:

100	158	212	263	310	354	395	433	470	
	(190)						(438)		
R5	R4	R3	R2		L4	L5	L6	L7	
503	535	565	593	620	646	650			
L8	L9	L10	L11	L12	L13				

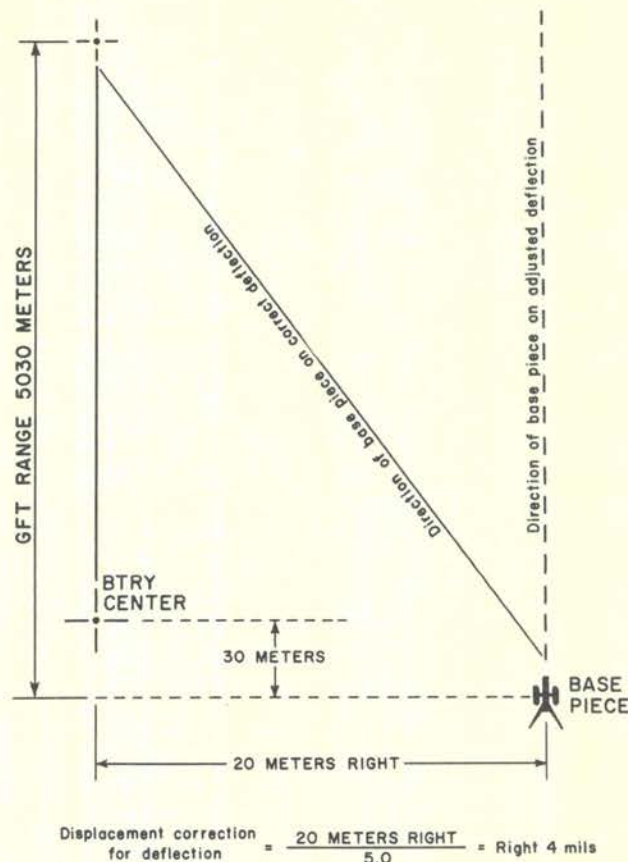
2. It is apparent that at the midpoint of the two adjusted elevations the difference between the total deflection corrections is 4 mils (R1 to L3). The deflection correction scale is revised by a graphical portrayal, using graph paper or a target grid. (This graph may be used in place of the deflection correction scale). The two total deflection corrections (R4 and L6) are plotted on the graph opposite each adjusted elevation, and a straight line is drawn through the two points extending to the limits of the elevation scale (fig. 20-7).

3. The deflection correction scale is now constructed by extracting the total deflection corrections from the graph for each drift block. The graph is entered with the value of the elevation for the drift change lines. The revised scale as determined from the graph in figure 20-7 is as follows:

100	158	212	263	310	354	395	433	470	503
	(190)						(438)		
R5	R4	R3	R1	L1	L3	L4	L6	L7	L9
535	565	593	620	646	650				
L10	L11	L12	L13	L14					

4. In those cases where the overlapping total deflection corrections differ by two mils, the average of the total deflection corrections is used. If the difference is one mil, the even total deflection correction is used.

(b) When corrections are based on one registration and one met plus VE solution, the possibility exists that a position deflection error is included in the total deflection correction to the registration point. This position de-



★Figure 20-5. Base piece displacement correction-deflection.

rection correction is isolated and then applied to the met deflection correction.

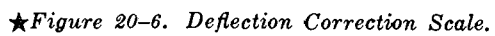
1. Assume that a registration and concurrent met resulted in the following data:

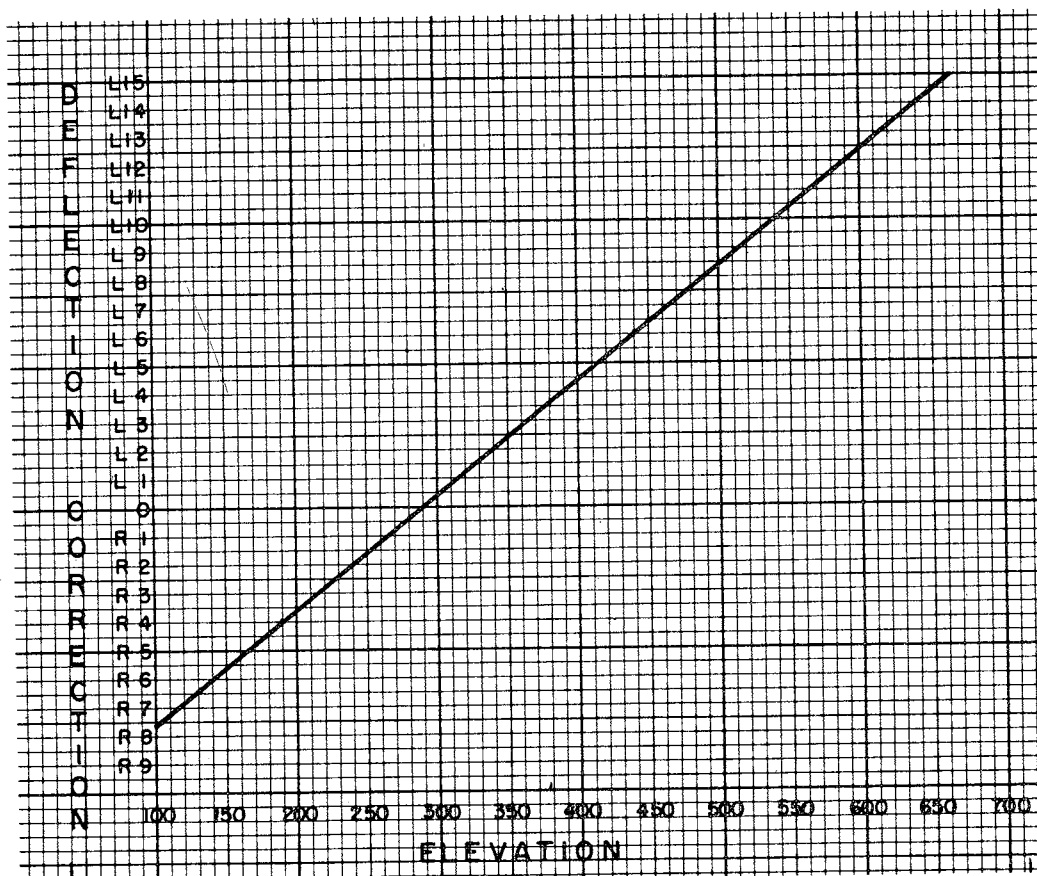
Adjusted elevation	190
Total deflection correction	R4
Met deflection correction	R2

2. Assume that a met plus VE solution to a target in the same direction as the registration point but at a greater range resulted in the following data:

Adjusted elevation	358
Met deflection correction	L8

3. To isolate the position deflection error, subtract the met deflection correction to the registration point (R2) from the total de-





★Figure 20-7. Deflection corrections for overlapping drift blocks.

flection correction (R4) to obtain the position deflection correction.

“Position deflection correction”

$R2 (R4 - R2)$

4. To obtain the total deflection correction at elevation 358, add the position deflection correction, which is considered a constant, to the met deflection correction to the target.

5. Using the two total deflection corrections (R4 and L6), follow the steps outlined for the two-plot deflection correction scale with overlapping drift blocks.

(3) *Multiple-plot GFT setting.* When three or more total deflection corrections are determined, each total deflection correction is used as the basis for constructing the deflection correction scale halfway toward each adjacent total deflection correction. When overlapping differences are obtained, reconcile

them by following the procedures for construction of the two-plot deflection correction scale.

b. After the deflection correction scale has been constructed on the GFT, the total deflection correction for any point within transfer limits can be determined by placing the hair-line over the chart range and reading the total deflection correction in the drift block that is adjacent to the elevation to be fired. This correction is applied to the chart deflection and the sum is transmitted to the firing battery.

20-14. Transfer Limits—Deflection

a. When valid meteorological data have been determined and wind cards (para 21-18) are being used, registration deflection corrections may be applied throughout 6400 mils.

b. When valid meteorological data have not been determined and/or wind cards are not being used, registration deflection corrections

are valid within the following transfer limits:

(1) When the GFT range is 10,000 meters or less—400 mils left and right of the battery-registration point line.

(2) When the GFT range is greater than 10,000 meters—4,000 meters left and right of the battery-registration point line.

Section IV. REPLOTTING TARGETS

20-15. General

Only those targets requested by the observer or directed by the S3 will be replotted. Data for replot consist of the grid coordinates, altitude, fuze, and target number. Fire-for-effect chart data, particularly altitude (site), are not always precise. Within the battalion, fire-for-effect data, if used again without changing ammunition lots or without an appreciable change in weather, will usually cause effective fire to fall on the target. However, if target locations are sent outside the battalion or if targets are refired with different corrections for nonstandard conditions, the replotted target coordinates and altitude must indicate the actual ground location as nearly as possible. The more accurately corrections are known and applied, the closer the replot data will correspond to the actual ground location of the target. The procedures for determining replot data differ with the type of fuze used in fire for effect.

20-16. Point Detonating Fuze

a. During the adjustment of point-detonating fuze, the observer seldom corrects for difference in altitude; therefore, the site fired is often not the true site to the target. Any error in site will be reflected as a range error on the firing chart. If the true site to the target is computed and then subtracted from the quadrant elevation used in fire for effect, the resulting elevation can be used to determine the range to the target. True site is determined by successive approximation using a map.

★b. Since known total deflection corrections are applied throughout each mission, the fire-for-effect chart deflection will serve as the replot deflection. The difference between the total deflection correction for the initial target location (used throughout the mission) and the total deflection correction for the fire-for-effect location is small and may be ignored.

c. The adjusting battery computer announces the chart deflection and chart range for the initial replot to the horizontal control operator unless the pin is in the final location. The HCO polar plots the target from the adjusting battery center at the range and deflection announced. He then announces the grid coordinates to the vertical control operator. The VCO plots the coordinates and determines the map altitude at the replotted location. Using this altitude and the range at which the target is now plotted, the VCO computes a new site and announces this site to the computer.

d. If the site announced by the VCO does not agree within 1 mil of the site fired, the computer subtracts the new site from the quadrant elevation and uses the resulting elevation to determine a new replot range. The replot deflection remains the same.

e. The HCO polar plots this new data and announces the coordinates to the vertical control operator. The VCO plots these grid coordinates and determines the map altitude of the replotted location. This procedure, referred to as successive approximation, is repeated until the site announced by the VCO agrees within 1 mil of the site previously computed.

f. When the site announced by the VCO agrees with, or within 1 mil of, the previous site computed, the computer uses the final site to compute the final elevation.

g. The computer announces the final replot range based on the final elevation. The HCO polar plots the target at the deflection and range announced by the computer. He then announces the coordinates to be recorded to the computer. The VCO announces the altitude used to determine the final site. The computer records the coordinates, altitude, fuze used in fire for effect, and target number on the computer's record.

★h. The example below is based on the following data: Battery A, 155-mm howitzer

M109, altitude of battery 405 meters, GFT setting: GFT A: Charge 4, lot ZT, range 5270, elevation 350.

Fire-for-effect data: Target AF2601 (charge 4, fuze quick).

Deflection fired	3,214 mils.
Chart deflection	3,206 mils.
Quadrant fired	373 mils.
Site initially computed	-11 mils.
Fire-for-effect elevation (373- (-11))	384 mils.

Computer to HCO:

Replot deflection (fire-for-effect chart deflection)	3,206 mils.
Replot range (range corresponding to elevation 384)	5,630 meters.

The HCO polar plots the target deflection 3206 and range 5630.

He reads and announces the coordinates 43713421 to the VCO.

The VCO plots the coordinates and determines the altitude of the point to be

366 meters.

The VCO computes the first apparent site and announces it to the computer (vertical interval -39 meters, range 5630)

-8 mils.

Computer determines the first apparent elevation (373-(-8)) ...

381 mils.

Computer to HCO:

Replot deflection	3,206 mils.
Replot range (range corresponding to elevation 381)	5,600 meters.

The HCO polar plots, using these data, and announces coordinates 43743417, to the VCO. The VCO plots the coordinates and determines the altitude of this point to be

363 meters.

The VCO computes the second apparent site and announces it to the computer (vertical interval -42 meters, range 5600)

-9 mils.

Site agrees within 1 mil of last site computed. Computer determines the adjusted elevation (373-(-9))

382 mils.

Computer to HCO:

Replot deflection	3,206 mils.
-------------------------	-------------

Replot range (range corresponding to elevation 382). 5,610 meters. The HCO polar plots, using these data, and announces replot coordinates 43733416 to the computer. The VCO announces altitude used to determine final site (-9 mils): replot altitude 363 meters.

Data to be recorded:

Coordinate is 43733416, altitude 363 fuze quick, target AF 2601.

20-17. Fuze VT

Replot of targets attacked with VT fuze is accomplished as described in paragraph 20-16 for point-detonating fuze, except that quadrant elevation and site used in the successive approximation is the quadrant elevation and site used in fire for effect minus the height-of-burst correction (20/R) that was fired.

★20-18. Fuze Time

a. When a target in a fuze time mission is replotted, the replot range is that range corresponding to the fire for effect time. This is accomplished by placing the time gageline over the fire for effect time and reading the range under the hairline.

b. The computer announces the replot range and deflection to the HCO. He then determines the new elevation (elevation gageline corresponding to the replot range (hairline) and the total site fired by subtracting the elevation from the fire for effect quadrant elevation. Ground site is then determined by subtracting 20/R, determined at the replot range, from the total site fired. The VCO, using the GST, determines the new VI, algebraically adds it to the altitude of the battery, and announces the sum as the altitude of the target. The HCO announces the replot coordinates of the target. The computer announces data for replot as follows: DATA FOR RELOT: COORDINATES 43733416, ALTITUDE 363 METERS, FUZE TIME, TARGET ALFA CHARLIE 2601.

★20-19. Replotting Targets With Refinement Data

a. *Point Detonating Fuze.* When a mission fired with point detonating fuze is ended with refinement data, the corrections are plotted on the firing chart and new chart data is determined. The new chart deflection is the replot deflection. The computer determines the new quadrant elevation based on the new range and the site fired. This quadrant elevation is used for replotting the target as outlined in paragraph 20-16.

b. *Variable Time Fuze.* Replot of targets fired with variable time fuze, when refinement data is announced, is accomplished as described for point detonating fuze except that the quadrant elevation used in the successive approximation is the quadrant elevation determined to the final pin location minus the height-of-burst correction (20/R) that was fired.

c. *Mechanical time fuze.* When refinement data is announced for targets fired with mechanical time fuze there are several possibilities that may exist.

(1) Refinement data may include a correction for range or deviation, or both. Since there is no correction for height of burst it must be assumed that a 20 meter height-of-burst exists. In this situation, the refinement corrections are plotted on the firing chart and new chart data determined. The new deflection is the replot deflection. The computer determines a new fuze setting and quadrant elevation based on the new range and applies the total height of burst correction, determined during the adjustment, to the new fuze setting to determine the fuze setting that would be used if the data were to be fired. With this fuze setting, final chart deflection, and quadrant elevation, the target is replotted as outlined in paragraph 20-18.

(2) Refinement data may include a correction for range or deviation, or both, and a correction for height of burst. It must be remembered that the current procedure for adjusting height of burst by using Δ FS will cause a lateral change in burst location as far as the observer is concerned. Consider the following example of an observers correction: LEFT 20, ADD 30, DOWN 10, RECORD AS

TARGET, END OF MISSION. By plotting the range and deviation corrections on the firing chart and also considering the height of burst correction in determining a new fuze setting, an error would be introduced into the replot location by the amount of the lateral change caused by the Δ FS used. The interest at this time, is not computing data to fire but in the location of a point. With this information we can proceed as in (1) above by plotting the range and deviation corrections, ignoring the height of burst correction, and determining the chart deflection, quadrant elevation, and fuze setting that includes the total height of burst correction determined during the adjustment. It is now assumed that this data will produce a mean burst location of range correct, line, with a height of burst of 30 meters. This height of burst will influence the determination of the VI. The total site determined will not contain 20/R at replot range but 30/R at replot range. Therefore, 30/R is subtracted from the total site to determine the ground site. Altitude is determined in the normal manner.

(3) Refinement data may contain only a height of burst correction. In this case the observer has indicated that range and deviation are correct but that the height of burst is other than 20 meters and the actual height of burst must be considered. Consider the following example of an observers correction: UP 10, RECORD AS TARGET, END OF MISSION. The observer has indicated that a 10 meter height of burst exists and the total site contains 10/R at replot range rather than 20/R. In this case 10/R is subtracted from the total site to determine ground site and replot is performed in the normal manner.

CHAPTER 21

METEOROLOGICAL CORRECTIONS AND VELOCITY ERROR

Section I. METEOROLOGICAL CORRECTIONS

21-1. General

Among the conditions that affect a projectile after it leaves the tube is the state of the atmosphere through which the projectile passes. The three properties of the atmosphere that the United States Field Artillery considers in its gunnery computations are wind (direction and speed), air temperature, and air density. The meteorological (met) message contains current ballistic information about atmospheric conditions.

*21-2. Types of Meteorological Messages

Two types of met messages are provided for artillery fire. The type 2 message is used with air defense artillery cannon. The type 3 message is used for field artillery cannons and free rockets firing at surface targets and is the type with which the field artillery is concerned. The introductory portion of the tabular firing tables for each weapon specifies which type of met message is to be used for that weapon; e.g., paragraph 8d, page xxvii, FT 155-AH-2, states that type 3 messages will be used at all elevations of all charges for the M109 howitzer.

*21-3. The North Atlantic Treaty Organization Meteorological Message

a. Data contained in cannon artillery firing tables are based on the International Civil Aviation Organization (ICAO) atmospheric structure. The firing tables are arranged in sequence and format which coincides with the North Atlantic Treaty Organization (NATO) Meteorological Message.

b. The NATO met message is divided into an introduction and a body.

INTRODUCTION

Group 1	Group 2	Group 3	Group 4
METB30	512018	070950	049982

BODY

002618	009976	012618	009978	022720	008978
032924	004981	042927	002982	053129	004987

(1) The introduction to the NATO met message consists of four 6-character groups.

(a) *Group 1.* The first three letters (MET) in group 1 designate the transmission as a met message. The next letter (B) indicates that it is a ballistic met message. The first digit indicates the type of met message (2 or 3). The last digit (0) is the designation of the octant of the earth in which the met station is located. In this case, 0 designates that the met station is located in north latitude between 0° and 90° west longitude. The key to the octant designation code is as follows:

Code number	Octant
0	North latitude, 0° to 90° west longitude
1	North latitude, 90° to 180° west longitude
2	North latitude, 180° to 90° east longitude
3	North latitude, 90° to 0° east longitude
4	Not used
5	South latitude, 0° to 90° west longitude
6	South latitude, 90° to 180° west longitude
7	South latitude, 180° to 90° east longitude
8	South latitude, 90° to 0° east longitude
9	Used for coded identification

(b) *Group 2.* Group 2 (512018) designates the center of the area in which the met message is valid. This may be expressed in tens, units, and tenths of degrees of latitude and longitude (51 12' north latitude, 01 48' west longitude). When the number 9 is used to designate the octant, the six digits or letters are the coded location of the meteorological unit which produced the met message.

(c) *Group 3.* The first two digits in group 3 (07) represent the day of the month on which the message becomes valid. The next three digits (095) indicate the hour at which the met message becomes valid in tens, units, and tenths of hours (0930). The hour refers to *Greenwich mean time*, and each firing table contains an appendix and World Time Zone Map which is used to convert Greenwich mean time to local time. The last digit in group 3 indicates the number of hours the message will remain valid, i.e., 1 to 8 hours, and the digit 9 represents 12 hours. Some NATO countries

use a system to predict weather and, therefore, the length of time that the message will remain valid. The United States does not attempt to predict the length of time a met message will remain valid; instead, during combat, the United States normally obtains new met data on a 2-hour schedule. Therefore, the last digit in group 3 of a NATO met produced by the United States is always 0.

(d) *Group 4.* The first three digits of group 4(049) indicate the altitude of the met station meteorological datum plane (MDP) above mean sea level in tens of meters (490 meters). The next three digits (982) indicate the atmospheric pressure at the MDP, expressed as a percentage (to the nearest 0.1 percent; of the ICAO standard at nospheric pressure at mean sea level.

(2) The body of the met message consists of a number of met message lines (up through 16) and each line consists of two 6-number groups. Each line contains the ballistic weather data for a particular altitude zone. Ballistic data are weighted averages of the conditions that exist from the surface up through the altitude zone indicated by the number.

(a) The first two numbers of group 1 indicate the met line number. The line number identifies a NATO altitude zone. The lines are numbered in sequence from 00 (surface conditions) through 16 (20,000 meters). Line number 03 is used as an example in (b) through (e) below.

(b) The next two digits in this group (29) indicate the direction from which the ballistic wind is blowing expressed as hundreds of mils (2900) true azimuth.

(c) The last two digits in this group (24) indicate the speed of the ballistic wind expressed in knots.

(d) The first three digits of the second group (004) indicate the ballistic air temperature expressed as a percentage (to the nearest 0.1 percent) of the ICAO standard temperature.

(e) The last three digits of this group (981) indicate the ballistic air density expressed as a percentage (to the nearest 0.1 percent) of the ICAO standard density.

Note. When a value is greater than 100 percent the initial digit 1 is omitted, i.e., 017 represents 101.7 percent.

★ 21-4. Selection of Meteorological Message Line

One of the keys to the proper solution of the met message is the selection of the proper line of the message. The proper line is that for the altitude closest to the summit of the trajectory.

a. The maximum ordinate (height of the summit of the trajectory above the gun) is a function of quadrant elevation and muzzle velocity (charge). The proper line number can be determined by entering the Line Numbers of Meteorological Message table (table A) for the appropriate charge with the adjusted quadrant elevation for the point for which the met message is to be solved.

b. If a met message is being solved prior to firing, no adjusted quadrant elevation is known. The line number is determined by entering the Complementary Range Line Number table (table B) for the appropriate charge at the chart range and height of target above gun, both to the nearest 100 meters.

Section II. VELOCITY ERROR

21-5. General

a. The best way to determine corrections is by registration. Corrections determined from a registration compensate for the combined effects of all nonstandard conditions which existed at the time of the registration. A portion of the registration corrections compensate for nonstandard conditions which can be measured at the time that the registration is being fired. The nonstandard condi-

tions which can be determined are—

- (1) Ballistic wind (from met message).
- (2) Ballistic air temperature (from met message).
- (3) Ballistic air density (from met message).
- (4) Weight of projectile (from firing battery).
- (5) Drift (from firing tables).
- (6) Propellant temperature (measured at gun position).
- (7) Rotation (from firing tables).

b. Corrections for the nonstandard conditions listed in *a* above can be computed by using the firing tables.

★ *c.* There are ballistic variations from firing table standards which cannot be measured (wear of tube, moisture content of the propellant, shell surface finish, etc.). Corrections for these unknown variations are included in the corrections determined from a registration. For convenience, the total of the unknown variations are grouped together and termed "velocity error" (VE). The variations which compose velocity error include—

(1) Factors affecting developed muzzle velocity.

(2) Factors affecting the ballistic coefficient of the projectile.

(3) Mechanical limitations and small errors in survey, charts, FDC equipment, and fire control instruments.

★ *d.* Velocity errors are assumed to be a measure of weapon and ammunition performance and are not considered subject to change in weather and other measurable nonstandard conditions. Velocity error is expressed as meters per second (m/s). The computed VE should be treated as a constant until evidence from firing indicates it should be changed.

★ 21-6. Determination of Velocity Error

The determination of velocity error requires that the observations upon which the met message is based be concurrent with a registration. The determination of velocity error is accomplished by the following steps:

a. Determine the total range correction from the registration (para 20-3).

b. Compute the met range correction. For convenience, correction for nonstandard projectile weight and rotation of the earth together with corrections for ballistic range wind, air temperature, and air density are considered met range corrections.

c. Determine the Δ range correction. The symbol " ΔV " is used to represent the total variation from standard muzzle velocity. In the present context, ΔV is the sum of VE and the change to muzzle velocity due to change in propellant temperature.

ΔV range correction is determined by subtracting the met range correction from the total range

correction.

d. Convert the ΔV range correction to ΔV in meters per second.

e. Compute the velocity error (para 21-11).

★ 21-7. Entry Range

It is necessary to determine the range (entry range) at which to extract unit corrections. The entry range is the sum of the chart range to the point for which the met message is being solved and the complementary range. Complementary range is the range correction corresponding to the complementary angle of site and is determined from the firing tables. To determine complementary range, enter Complementary Range Line Number table (table B) with the chart range to the nearest 100 meters and the height of target above the gun to the nearest meter. Interpolation for height of target above the gun may be necessary.

Example: 155-mm howitzer M109, charge 5 green bag, chart range 7020, altitude of battery 237, altitude of target 500. There is no base piece displacement for range.

Height of target above gun, +263 meters. Enter table B at range 7000 and height of target above gun +263.

Height of target above gun			
7000	+200	(+263)	+300
	54	(72.3)	83

Complementary range is +72 meters. Entry range is 7092 (7020 + 72).

21-8. Determination of Total Range Correction

a. The total range correction is best computed in the manner described in paragraph 20-3.

b. The total range correction may also be computed by subtracting the entry range (to the nearest meter) from the range corresponding to the adjusted elevation plus comp site.

21-9. Computation of Meteorological Corrections

★ Met range and deflection corrections are computed concurrently. Firing table data are based on an assumed standard trajectory which exists under prescribed standard conditions of weather and materiel. If the variation between an exist-

ing condition and the assumed standard condition is measured, a correction for that variation can be determined by multiplying the variation by a correction for each unit of variation. Unit corrections are contained in the firing tables. The Met Data Correction Sheet (DA Form 6-15) is used as an aid in computing met corrections. An example of the solution of a met message and the use of the met data correction sheet (fig 21-1) is shown below.

Example: Assume that a 155-mm howitzer M109 battery has registered and the following information is available:

Adjusted data to registration point:

Elevation	368 mils
Quadrant elevation	374 mils
Deflection	3,209 mils
Time	24.6

Chart data to registration point:

Range	7,230 meters
Deflection	3,220 mils
Site	+ 6 mils

Additional information:

Latitude of battery	34° N
Altitude of battery	321 meters
Altitude of registration point	358 meters
Azimuth to registration point	1,820 mils

Weight of projectile	5 squares
Propellant temperature	62° F
Charge	5 GB
Lot	XY

Concurrent met message:

METB31	344983	120950	030031		
004717	021016	014817	024018	025118	029019
035120	031021	045221	033023	055220	033022

a. Enter all known data in the proper spaces on the form, i.e., charge, adjusted quadrant elevation, chart range to the nearest 10 meters, altitude of battery, height of target above gun, latitude to the nearest 10°, direction of fire to the nearest 100 mils, propellant temperature, and weight of projectile.

b. Enter data from the introduction to the met message.

c. Determine the proper met message line number (para 21-4). Enter data from the met message line number on the form.

d. Determine the complementary range. Enter complementary range and add it to chart range to determine the entry range (para 21-7).

MET DATA CORRECTION SHEET (FM 6-40)									
BATTERY DATA					MET MESSAGE				
Charge	Adj QE	Chart Rg	Latitude	Type Msg	Octant	Area/Unit			
568	374	7230	30°N	MTA 3	1	344983			
Alt of Btry (10m)		320		Date	Time	Alt MDP	Pressure		
				12	0930	300	103.1		
Alt of MDP		300		Line Nr	Wind Dir	Wind Spd	Air Temp		Air Density
				03	5100	20	103.1		102.1
Btry (above/below) MDP (Δh)		+20		Δ h Corrections		+ 0.0		0 0.2	
Alt of Target (nearest) meter		358		Corrected Values		103.1		101.9	
Height of burst above target		---							
Alt of burst		358							
Alt of Btry (nearest) meter		321							
Height of Target (burst above gun) (m)		+37		Comp Rg	Chart Rg	Entry Rg	7200		
				10	7230	7240			
WIND COMPONENTS AND DEFLECTION									
When direction of wind is less than direction fire add		6400		Total DF Corr R11 Met DF Corr L9 Pos DF Corr R20					
Dir of Wind		5100							
Dir of fire (1820)		1800		Rotation		0.9			
Chart Dir of Wind		3300		Drift		7.1			
Gross Wind	Wind Speed	20	Comp	0.10	2	Knots	0.33		Gross Wind
Range Wind	Wind Speed	20	Comp	0.99	Head	20	Knots	Met Defl	8.7
MET RANGE CORRECTIONS									
	Known Values	Standard Values	Variations from Standard	Unit Corrections	Plus	Minus			
Range Wind	20	0	20	-10.1		202.0			
Air Temp	103.1	100%	3.1	-23.1		71.6			
Air Density	101.9	100%	1.9	+13.9		26.4			
Proj Weight	5	4	1	+26.0		26.0			
Rotation	-25 × 0.87					21.8			
					52.4				
					295.4				
					52.4				
					243.0				
					-243				
COMPUTATION OF VE									
	VE	-2.3	m/s	D +19.3	Total Range Corrections	-190			
Prop Temp	62° F	Change to MV for Prop Temp	-0.4	m/s	I -18.4	Met Range Correction			
	ΔV	-2.7	m/s	MV unit Corr +19.3	ΔV Range Correction	+53			
					Total Range Correction				
Old VE + New VE = -2 = Ave VE					m/s				
TI 24 MET FUZE CORRECTION									
	Variations from Standard	Unit Correction	Plus	Minus					
ΔV	2.7	-0.037		0.100					
Range Wind	20	+0.013		0.260					
Air Temp	3.1	+0.037		0.115					
Air Density	1.9	-0.015		0.028					
Proj Weight	1.0	-0.065		0.065					
			0.375	0.193					
			0.193						
			0.182						
Met Fuze Corr			0.182						
			0.375	0.193					
			0.193						
			0.182						
Old Fz Corr + New Fz Corr = -2 = Avg Fz Corr									
Correction #			Battery			Date/Time 12 1000 MAR 70			

DA FORM 6-15

REPLACES EDITION OF 1 OCT 60, WHICH IS OBSOLETE.

Figure 21-1. Solution of the met message.

e. Since grid convergence seldom exceeds 50 mils and the ballistic wind is measured to the nearest 100 mils, the true azimuth is considered to be the grid azimuth and requires no conversion.

★f. Compute the chart direction of the wind by subtracting the direction of fire from the direction of the ballistic wind. Enter the Wind Components table (table C) with the chart direction of the wind and determine the components of a 1-knot wind. Enter the components on the form.

★g. Compute the range wind and crosswind (to the nearest knot) and enter them in the appropriate spaces.

★h. Determine the difference in altitude between the meteorological datum plane (MDP) and the battery (Δh). Enter the Temperature and Density Corrections table (table D) with Δh (to the nearest 10 meters) to determine the corrections to air temperature and density. Apply corrections and enter corrected temperature and density in the appropriate blocks.

i. Enter the Propellant Temperature table (table E) with propellant temperature to the nearest degree to determine the change to muzzle velocity (to the nearest 0.1 meter per second). Enter the muzzle velocity change (to be used later in determination of VE).

j. Compute the variations from standard for range wind, temperature, density, and projectile weight.

k. Enter the Ground Data table (table F) at entry range (d above) rounded to nearest 100 meters to determine —

- (1) Drift correction.
- (2) Crosswind unit correction.
- (3) Muzzle velocity unit correction (extract both factors).
- (4) Range wind unit correction.
- (5) Air temperature unit correction.
- (6) Air density unit correction.
- (7) Projectile weight unit correction.

l. Determine the rotation corrections to range (table H) and azimuth (table I) and enter them. The Rotation tables (H and I) are entered at entry range to the nearest listed range, azimuth of fire to the nearest listed value, and latitude to the nearest 10° .

m. Compute the crosswind correction and then add rotation correction for azimuth, drift correc-

tion, and crosswind correction to determine the met deflection correction.

★n. Enter the Fuse Setting Factors table (table J) at the time corresponding to the adjusted elevation, to the nearest number listed, and determine the unit corrections for muzzle velocity (extract both factors), range wind, air temperature, air density, and projectile weight for the met fuze correction.

o. Multiply the variations from standard by the unit corrections and enter the results under the column headed Plus or Minus, whichever is appropriate. The sign of each range correction is the same as the sign of the corresponding unit correction.

★p. Add the values in each column. Find the difference between the two columns (Plus and Minus) and round off to the nearest meter; the result is the met range correction.

★ 21-10. Determination of ΔV

a. The ΔV range correction is determined by subtracting the met range correction (para 21-9) from the total range correction (para 20-3).

b. The ΔV range correction is converted to meters per second by dividing the ΔV range correction by the muzzle velocity unit correction (Ground Data table). The sign of the ΔV range correction is always opposite to the sign of the ΔV . If the ΔV range correction is *plus*, the unit correction from the *Decrease* column is used; if the ΔV range correction is *minus*, the unit correction from the *Increase* column is used.

★21-11. Computation of Velocity Error

The velocity error in meters per second is computed by subtracting the change to muzzle velocity for propellant temperature (para 21-9) from ΔV (para 21-10).

★21-12. Average Velocity Error

a. A velocity error (VE) is computed whenever a registration and met message are concurrent. The VE includes all nonmeasurable variations from standard conditions. Some variations are relatively constant (tube wear, ballistic coefficient, etc.) whereas others are unpredictable (propellant variation, minor weather variations, etc.). In order to smooth out these errors, each new

velocity error determined is averaged with the previous velocity error (which may be an average VE) determined at the same position. This method gives most weight to the most recently determined VE but does not disregard the previous velocity errors.

Example:

VE determined at 0800 is — 3.2 m/s

VE determined at 1000 is — 3.8 m/s

Average VE to be used after 1000 is —3.5 m/s

$$\frac{(-3.8) + (-3.2)}{2}$$

VE determined at 1400 is —4.5 m/s

Average VE to be used after 1400 is —4.0 m/s

$$\frac{(-4.5) + (-3.5)}{2}$$

b. A velocity error is considered valid only for the position, weapon, charge, and propellant for which it was determined. When a unit has displaced and cannot register immediately, the average VE from the previous position may be used but transfers may not be accurate. As soon as a VE is determined in the new position, it is used while in that position. At the same time, it is averaged with VE's from previous positions for use in a future position when registration is not possible.

21-13. Computation of Meteorological Fuze Correction

a. The fuze setting corresponding to the adjusted elevation plus complementary angle of site approximates the correct fuze setting. In low-angle fire, comp site is usually negligible and has little effect on fuze setting. For this reason, comp site is normally considered only for nuclear fires or for firing large vertical angles or extreme ranges. Since, under nonstandard conditions, fuze setting varies at a slower rate than does elevation, a more accurate fuze setting can be obtained by correcting, for nonstandard conditions, the fuze setting corresponding to the adjusted elevation. Fuze setting change tables (table J) are designed to compensate for the same nonstandard conditions which affect range.

(1) *Met fuze correction.* The met fuze correction is equal to the algebraic sum of the individual fuze setting correction required to compensate for variations from standard conditions. The met

fuze correction for nonstandard conditions is determined by multiplying the unit factors by the corresponding departures from standard. Those changes which increase and those which decrease the fuze setting are added separately. The smaller sum is subtracted from the larger sum to find the met fuze correction, and the result is expressed to the nearest tenth. The sign of the correction will be that of the column with the larger sum.

(2) *Total fuze correction.* The total fuze correction is determined by subtracting the fuze setting corresponding to the adjusted elevation from the adjusted time.

(3) *Fuze correction.* The fuze correction is determined by subtracting the met fuze correction from the total fuze correction.

b. The use of the fuze setting change tables eliminates the error in assuming that the fuze correction is constant. The technique involved is similar to that in determining velocity error in that the effect of nonstandard conditions on fuze setting is computed at the time of the registration and subtracted from the total fuze correction. When a current met message is received, a met fuze correction is computed in much the same manner as a met range correction. The fuze setting corresponding to the new adjusted elevation is determined and the total fuze correction (met fuze correction plus the fuze correction) is added to this fuze setting to obtain the new adjusted fuze setting.

★*Example:* This is a continuation of the example in paragraph 21-9. GFT B: Charge 5, lot XY, range 7,230, elevation 368, time 24.6. The total fuze correction is +0.3 (24.6 — 24.3). The concurrent met is solved and yields a met fuze correction of +0.2. This is subtracted from the total fuze correction and the resulting fuze correction (+0.1) is filed for future use. Later, a new met is received and solved as in paragraph 21-14, resulting in the following GFT setting: GFT B: Charge 5, lot XY, range 7,230, elevation 370. The met fuze correction determined from the new met (+0.1) is added to the fuze correction determined above (+0.1) to obtain the total fuze correction (+0.2) to be applied to the fuze setting corresponding to the met corrected elevation (370). Thus, the GFT fuze setting is 24.6 (24.4 + (+0.2)).

Section III. APPLICATION OF METEOROLOGICAL AND VELOCITY ERROR CORRECTIONS

21-14. Application of Velocity Error

a. Frequently, it is undesirable to register each time there is a significant change in weather. In order to keep range corrections current under such a situation, a technique called met plus VE is used. The major change in corrections is due to changes in met conditions and propellant temperature. A new met message will provide current met conditions; VE is virtually constant. A total range correction is determined by adding current met range corrections to ΔV range corrections determined from the position average VE in meters per second and current corrections to muzzle velocity for propellant temperature. The total range correction is applied to the GFT setting range in the same manner as a range correction determined from a registration. A GFT setting is made by placing the hairline at the GFT range and constructing the elevation gageline at the elevation corresponding to the corrected range (GFT range plus the total range correction).

b. ΔV in meters per second is converted to a ΔV range correction by multiplying the ΔV by the muzzle velocity unit correction; the result is always given the sign of the unit correction used. The unit correction is determined at the range used to solve the met message and is taken from the DECREASE column if the ΔV is minus and from the INCREASE column if the ΔV is plus.

★ c. The following is an example of a met plus VE problem and is a continuation of the sample problem presented in paragraph 21-9. A subsequent met message and current propellant temperature are as follows:

METB31	344983	121150	030031		
004116	014963	014015	011964	024116	011964
034218	011966	943917	013966	054118	013968

Current propellant temperature 81° F.

Solution (fig 21-2):

Met range correction -202 meters

VE -2.3 m/s

Change to MV for propellant

temperature +0.5 m/s

ΔV -1.8 m/s

MV unit correction +19.3 meters

ΔV range correction (19.3×1.8) +35 meters

Total range correction (-202 +

+35) = -167) 170 meters

GFT range	7,230 meters
Corrected range ($7230 + (-170)$)	7,060 meters
Elevation for range 7060	370 mils
Fuze setting for elevation 370	24.4
Met fuze correction	+0.1
Fuze correction	+0.1
Total fuze correction	+0.2
Corrected fuze setting ($24.4 + (+0.2)$)	24.6
Position deflection correction	R20 mils
Met deflection correction	L4 mils
Total deflection correction	R16 mils

GFT setting:

GFT B: chg 5, lot XY, rg 7230,

el 370, ti 24.6.

21-15. Determination of Range Corrections for Targets Outside Transfer Limits

a. The use of the current VE is not restricted to transfer limits of the point at which the VE was determined. However, corrections determined close to minimum and maximum ranges are less accurate.

b. Corrections for targets outside transfer limits can be computed by using the met plus VE technique. The met corrections are determined by using the chart range, vertical interval, and direction to the target in question. ΔV is converted to a ΔV range correction by using the MV unit correction determined at the entry range for the target.

21-16. Deflection Corrections

a. Corrections for deflection and range are best determined from a registration. As a result of the initial registration, a deflection correction scale is constructed. The deflection correction scale indicates the total deflection correction for a given elevation. Total deflection correction is equal to the met deflection correction plus the position deflection correction.

b. A change of the total deflection correction as determined from a second registration or from a new met message will modify this deflection correction scale. To modify the total deflection correction by the correction determined from a met message it is necessary to know the amount of the total deflection correction that was due to weather. This requires a met message taken concur-

rently with the registration. If a later met message indicates a weather change a new deflection correction scale must be constructed. The new total deflection correction will be the algebraic sum of the position deflection correction and the new met deflection correction.

c. For example, a registration has been conducted and a concurrent met message has been solved for a 155-mm howitzer M109 firing charge 5 green bag.

(1) Corrections from registration and met message:

Chart deflection 3200 mils
 Adjusted deflection (initial
 registration at 1600 hours) 3186 mils
 Total deflection correction at the
 adjusted elevation (1600 hours) right 14 mils
 Met deflection correction (1600 hours) right 8 mils
 Position deflection correction right 6 mils

(2) At 2200 hours, new met corrections are computed (no registration):

Met deflection correction
 (2200 hours) right 10 mils
 Position deflection correction right 6 mils
 Total deflection correction at
 met corrected right 16 mils
 elevation ($R10 + R6$)

(3) The next morning at 0600 hours a second registration is conducted and new met corrections are computed:

Chart deflection (0600 hours) 3200 mils
 Adjusted deflection 3191 mils
 Total deflection correction at the
 adjusted elevation right 9 mils
 Met deflection correction at 0600 hours right 1 mil
 Position deflection correction right 8 mils
 Average position deflection correction right 7 mils
 ($R6 + R8 = R14/2$).

(4) At 1000 hours, new met corrections are computed (no registration):

Met deflection correction (1000 hours) left 2 mils
 Average position deflection correction right 7 mils
 Total deflection correction at met
 corrected elevation right 5 mils

(5) At 1400 hours, a new message is computed (no registration):

Met deflection correction (1400 hours) right 3 mils
 Average position deflection correction right 7 mils
 Total deflection correction at met
 corrected elevation right 10 mils

d. The data in c above may be tabulated for ready reference as follows:

Registration Data

Time	Chart df	Adj df	Regis df corr	Met df corr	Pos df corr	Avg pos df corr	Total df corr
1600	3200	3186	R14	R8	R6	...	R14
2200	---	---	---	R10	R6	---	R16
0600	3200	3191	R9	R1	R8	R7	R9
1000	---	---	---	L2	---	R7	R5
1400	---	---	---	R3	---	R7	R10

MET DATA CORRECTION SHEET									
BATTERY DATA					MET MESSAGE				
Charge	Adj QE	Chart Rg	Latitude	Type Msg	Octant	Area/Unit			
56A	374	7230	30°N	Meta 3	1	344983			
Alt of Btry (10m)		320		Date	Time	Alt MDP	Pressure		
				12	1130	300	703.1		
Alt of MDP		300		Line Nr	Wind Dir	Wind Spd	Air Temp	Air Density	
				03	4200	18	101.1	96.6	
Btry (above MDP (Δh) below)		+20		Δh Corrections		+ 0.0		+ 0.2	
Alt of Target (nearest meter)		358		Corrected Values		101.1		96.4	
Height of burst above target		-----							
Alt of burst		358							
Alt of Btry (nearest meter)		321							
Height of Target (burst above gun (m))		+37		Comp Rg	Chart Rg	Entry Rg	7200		
				+10	7230	7240			
WIND COMPONENTS AND DEFLECTION									
When direction of wind is less than direction fire add		640		Pos DF Corr R20					
Dir of Wind		4200		Met DF Corr L 4					
				Total DF Corr R16					
Dir of fire (1820)		1800		Rotation Corr 0.9					
Chart Dir of Wind		2400		Drift Corr L 7.1					
Cross Wind	Wind Speed	18	x Comp	0.71	13	Knots	x 0.33	Cross Wind Corr	4.9
Range Wind	Wind Speed	18	x Comp	0.71	13	Knots	x 0.33	Met Defl Corr	3.7
MET RANGE CORRECTIONS									
	Known Values	Standard Values	Variations from Standard	Unit Corrections	Plus	Minus			
Range Wind	13	0	13	-10.1		131.3			
Air Temp	101.1	100%	1.1	-23.1		25.4			
Air Density	96.4	100%	3.6	-13.8		49.7			
Proj Weight	50	40	10	+26.0	26.0				
Rotation	-25 x 0.87						21.8		
						26.0	228.2		
							26.0		
							202.2	-202	
COMPUTATION OF VE									
	VE	-2.3	m/s	D +19.3	Total Range Corrections				
Prop Temp	81° F	Change to MV for Prop Temp	+0.5	m/s	I -18.4	Met Range Correction	-202		
	ΔV	-1.8	m/s	MV unit Corr +19.3	ΔV Range Correction	+35			
						Total Range Correction	-167	-170	
Old VE _____ + New VE _____ = _____ - 2 x Ave VE _____ m/s									
T1 24 MET FUZE CORRECTION									
	Variations from Standard	Unit Correction	Plus	Minus					
ΔV	1.8	-0.037		0.067					
Range Wind	13	+0.013	0.169						
Air Temp	1.1	+0.037	0.041						
Air Density	3.6	+0.016	0.058						
Proj Weight	1.0	-0.065		0.065	Total Fuze Corrections				
				0.268	Met Fuze Correction	+0.1			
				0.132	Fuze Correction	+0.1			
				0.136	Total Fuze Correction	+0.2			
Old Fz Corr _____ + New Fz Corr _____ = _____ - 2 x Avg Fz Corr _____									
Correction # _____ Battery _____ Date/Time 12 1200 MAR 70									

DA FORM 6-15

REPLACES EDITION OF 1 OCT 60, WHICH IS OBSOLETE.

Figure 21-2. Application of velocity error.

21-17. Deflection Corrections Outside Transfer Limits

A total deflection correction can be determined for accurately located targets outside transfer limits by solving the current met message to the target and determining the met deflection correction. The met deflection correction to the target is applied to the position deflection correction to the registration point to determine the total deflection correction to the target.

Example:

Total deflection correction at	
registration point range	right 5
Met deflection correction at	
registration point range	right 2
Position deflection correction	right 3
Met deflection correction at target	
range	left 1
Total deflection correction at target	
range (R3 + L1)	right 2

21-18. Wind Cards

Lateral transfer limits can be eliminated by applying corrections to deflection, fuze setting and range for the existing direction of the wind as reported in a current NATO met message. Wind cards provide a rapid means of determining deflection corrections in mils, fuze corrections, and range corrections in meters when direction and velocity of the wind and range and direction to the target is known. The wind cards contain correction for a 1-knot wind blowing from the chart direction, divided into two components: the cross wind correction perpendicular to the plane of fire and the range wind correction parallel to the plane of fire. The arguments for entering the deflection and range tables are the chart direction of the wind and range to the nearest listed values. The fuze setting tables are entered with the chart direction of the wind and the fuze setting to the nearest listed values.

21-19. Employment of Wind Cards

The use of wind card corrections is predicated on the availability of met data (wind direction and velocity). These data must be known at the time the GFT setting is determined from registration (or met plus VE computation) and also at the time

that firing data to the target are computed. If the required met support is available, the decision to use wind card corrections rests with the S3.

a. Corrections obtained from wind cards should be applied when suitable met data are provided and —

(1) Fire for effect without adjustment is required.

(2) The S3 decides that first-round accuracy is required in the adjustment phase of an observer-adjusted mission. This decision is based on the observer's accuracy in locating targets, the type of terrain in which fires are being adjusted, and the proximity of friendly elements to the target.

b. *Wind cards should not be used when —*

(1) Met support is not available.

(2) The target is within 400 mils of the registration point in deflection and fires are to be adjusted by an observer.

(3) The target is beyond 400 mils of the registration point in deflection, fires are to be adjusted by an observer, and the S3 decides that speed of initial fires is more important than first-round accuracy.

21-20. Transfer Limits

The use of wind cards greatly improves present transfer limits. Although range transfer limits are not affected, deflection transfer limits are expanded to a full 6,400 mils.

★ 21-21. Example Problem

The purpose of this problem is to illustrate the method by which information obtained from a registration and a met message may be used to compute data to a target. When a GFT setting and a total deflection correction are obtained, they represent corrections for all nonstandard conditions at the GFT range (met checkpoint range). Data can be accurately computed for targets at directions other than those at which the GFT setting was determined by applying the differences of the wind effects to chart deflection, fuze setting, and range.

a. *Known Data.*

(1) *Battery laying data.*

155-mm howitzer M109:

Azimuth 6,100 mils
Deflection 3,200 mils
Base piece is over battery center.

(2) *Registration data.*

Chart range 5,900 meters
Chart deflection 3,058 mils
Charge 5
Adjusted deflection 3,042 mils
Adjusted time 19.8
Adjusted elevation 306 mils
Site +14 mils

(3) *Extract of a recent NATO met message.*

012616 938002 022920 926004 033117 941005

b. *GFT Setting and Total Deflection Correction.*

GFT A: Chg 5, lot XY, rg 5900, el 306, ti 19.8

Total deflection correction R16.

c. *Wind Corrections to the Registration Point.*

Obtain and record registration point wind corrections for deflection, fuze, and range.

(1) *Met message line number.* Enter the wind card for charge 5 with the range corresponding to the adjusted QE ($306 + (+14) = 320 = \text{range } 6360$). Select the met message line number to be used and extract wind direction and speed.

Met message line number 02
Wind direction 2,900 mils
Wind speed 20 knots

(2) *Chart direction of the wind.* Find the chart direction of the wind by subtracting the azimuth of fire to the registration point from the azimuth of the wind, adding 6,400 mils to the wind azimuth when necessary.

Battery laid on deflection 3200 azimuth 6100
Chart deflection 3058 azimuth 6242
Chart direction of the wind ((2900 + 6400) — 6242) azimuth 3058

(3) *Corrections for a 1-knot wind.* Enter the wind card table for charge 5, using a chart range of 5900 meters. Find the correction for a 1-knot wind to deflection, fuze, and range opposite the nearest listed chart range to the registration point (6000) and under the nearest listed chart direction of the wind (3000).

Deflection correction R0.1
Fuze setting correction +0.01
Range correction —8

(4) *Wind correction.* Determine the wind corrections at registration point range by multiplying the corrections for a 1-knot wind obtained in (3) above by the wind speed as reported in the met message (20 knots). Round the crosswind correction to the nearest mil, the fuze setting correction to the nearest tenth, and the range correction to the nearest 10 meters.

Crosswind correction ($R0.1 \times 20$) R2
Fuze setting wind correction
($+0.01 \times 20$) +0.2
Range wind correction (-8×20) —160

d. *Transfer Data.* When a call for fire is received and it is desired to apply wind corrections they must be computed to the target. The wind corrections to the registration point are subtracted from the target data and the wind corrections to the target are added to the target data.

(1) *Target data.*

Charge 5
Chart deflection 2261
Chart range 4820
Site (Incl 20/R) +5

(2) *Range corresponding to uncorrected QE.* Determine the GFT elevation and fuze setting for the chart range to the target (4820). Add the site to obtain the QE. Determine the range corresponding to the uncorrected QE.

Elevation for range 4820 237
Uncorrected QE ($237 + (+5)$) 242
Fuze setting for range 4820 15.6
Range for QE 242 5120

(3) *Met message line number.* Enter the wind card for charge 5 with the uncorrected range (5120). Select the met message line number to be used and extract the wind direction and speed.

Met message line number 01
Wind direction 2600
Wind speed 16 knots

(4) *Chart direction of the wind.* Find the chart direction of the wind by subtracting the azimuth to the target from the azimuth of the wind, adding 6400 to the azimuth of the wind when necessary.

Battery laid on deflection 3200 azimuth 6100
Deflection to target 2261 azimuth 639
Chart direction of the wind
(2600 — 639) azimuth 1961

(5) *Correction for a 1-knot wind.* Enter the wind card tables for charge 5, using as arguments the chart direction of the wind (1961) and chart range to the target (4820), and determine the correction for a 1-knot wind to deflection, and range opposite the nearest listed chart range to the target and under the nearest listed chart direction of the wind to the target (2000). Determine the correction to fuze setting opposite the nearest listed fuze setting (14-29) and under the nearest listed chart direction of the wind.

Deflection correction	R0.2
Range correction	-2
Fuze correction	0

(6) *Wind corrections.* Determine the wind corrections to the target by multiplying the corrections for a 1-knot wind by the wind speed (16 knots). Round the crosswind correction to the nearest mil, the range wind correction to the nearest 10 meters, and the fuze setting wind correction to the nearest tenth.

Crosswind correction ($R0.2 \times 16$)	R3
Range wind correction (-2×16)	-30
Fuze setting wind correction	0

(7) *Wind corrected deflection.* Subtract the crosswind correction to the registration point (R2) from the chart deflection to the target (2261)

and add the crosswind correction to the target (R3) to obtain the wind corrected deflection.

Wind corrected deflection	
(2261 - R2 + R3)	2260

(8) *Wind corrected range.* Subtract the range wind correction to the registration point (-160) from the chart range to the target (4820) and add the range wind correction to the target (-30) to obtain the wind corrected range to the target

Wind corrected range	4950 meters
----------------------------	-------------

(9) *Data to fire.*

(a) *Deflection.* Set the GFT hairline over the wind corrected range (4950) and read the total deflection correction (R17). Add the total deflection correction to the wind corrected deflection to determine the deflection to fire.

Deflection to fire ($2260 + R17$)	2243
---	------

(b) *Fuze setting.* Read the fuze setting under the time gageline (16.1). Subtract the fuze setting wind correction to the registration point (+0.2) and add the fuze setting wind correction to the target (0) to obtain the fuze setting to fire.

Fuze setting to fire ($16.1 - (+0.2 + 0)$)	15.9
--	------

(c) *Quadrant elevation to fire.* Read the elevation under the elevation gageline (245). Add site (+5) to obtain the QE to fire.

QE to fire ($245 + (+5)$)	250
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Section IV. EXPERIENCE CORRECTIONS

21-22. General

In some situations, such as a hasty occupation of position or when restrictions are placed on registration, current registration or met corrections may not be known or obtainable. In such a case, the S3 must decide what corrections, if any, are to be applied to data to improve the accuracy of fires. Except in unusual cases in which prior knowledge of the weather, ammunition, and weapon is not available, the S3 will resort to an analysis of experience corrections as a basis for applying

corrections. This procedure is followed until met or registration corrections are available.

21-23. Experience Velocity Error Corrections

The average VE or the latest VE will be used as the basis for a GFT setting. It is better to establish a GFT setting with this information than to ignore it until a registration is accomplished.

21-24. Experience Meteorological (Range) Corrections

If a current met message is not available, the data

for a GFT setting may be improved by using corrections for weather, ammunition, and weapon performance determined from previous met messages and registrations. Estimating corrections based solely on such records should only be done with extreme caution.

21-25. Experience Fuze Correction

Evaluation of all previous time registrations of a specific fuze will invariably indicate that a relatively constant fuze correction is required to obtain the proper height of burst. This factor is the average fuze correction. The average fuze correction, if applied to the fuze setting correspond-

ing to the elevation for the initial round, should cause the round to burst at approximately the desired height. The fuze correction is considered a fuze characteristic, not a correction for weather conditions.

★ 21-26. Position Deflection Correction

When a position deflection correction is determined, it may be due to one or more errors in plotting, laying and/or survey. The S3 should keep in mind that errors causing the position deflection correction are difficult to isolate and remain relatively constant, for a given position. Therefore, a position deflection correction for one position cannot be used in a new position.

CHAPTER 22

CALIBRATION

Section I. GENERAL

22-1. Introduction

a. Calibration is the comparison of the muzzle velocity of a given piece with some accepted standard performance. That standard may be selected arbitrarily from the performance of a group of weapons being calibrated together, as in *comparative calibration*, or it may be the standard defined in the firing tables, as in *absolute calibration*.

b. Calibration makes it possible to group cannons of a given caliber and of nearly equal muzzle velocities into one battery so as to reduce the frequency with which individual piece corrections must be applied.

c. Calibration also serves the following purposes:

(1) It permits the determination and application of corrections to compensate for variations in muzzle velocity developed by individual pieces.

(2) The calibration VE may be used in computing a met plus VE GFT setting when no other data are available.

d. Both of the purposes in c above can be accomplished by absolute calibration. Only the purpose in c(1) above can be accomplished by comparative calibration.

22-2. Types of Calibration

a. Calibration can be accomplished with the aid of a muzzle velocity measuring device called a chronograph. When a chronograph is not available, calibration can also be performed with fall-of-shot procedures of varying complexity. Both techniques result in a variation from the accepted standard performance

expressed in feet per second or meters per second. The unit of measurement of the variation (feet or meters) is the same as the unit used in the firing tables for the weapon. A variation determined by chronograph is called muzzle velocity variation. A variation determined from fall-of-shot procedures, regardless of the complexity, is called velocity error.

b. Measuring the muzzle velocity developed by a weapon-ammunition combination results in *absolute calibration* data.

(1) Muzzle velocity variations (MVV) can be used to tie groups of weapons together provided a common lot of ammunition is used. Developed muzzle velocity is a function of two variables—the weapon and the ammunition—and, in order to use one as a basis of reference, the other must be kept constant. A group of weapons calibrated with a chronograph will be considered in a state of absolute calibration with respect to firing table standards if a common lot of ammunition is used.

(2) The VE determined from a fall-of-shot absolute calibration will not match muzzle velocity variation determined from an instrumental absolute calibration, unless the ballistic coefficient of the projectile lot is standard. Only if the ballistic coefficient change (BCC) is known and, therefore, can be subtracted from the fall-of-shot data as one of the non-standard conditions will the VE determined be absolute in the true sense. However, despite an unknown ballistic coefficient, the VE determined from fall of shot is valid for use with the met plus VE technique if the same propellant lot is used.

Section II. CHRONOGRAPH CALIBRATION

22-3. Frequency of Calibration

a. The type and caliber of weapon that is being fired and the frequency (by charge) of firing govern the need for calibration. All new tubes should be calibrated as soon after receipt as possible. Thereafter, any weapon in service should be recalibrated at least annually. If a great deal of firing takes place, recalibration may be needed more often. If an accurate and reliable record of the change in VE determined from registrations and concurrent met data is maintained, recalibration may not be necessary until the velocity loss becomes excessive (2 range probable errors). Wear tables can also give a general indication of the need for recalibration.

b. Ordnance teams are equipped with a pull-over gage to perform wear measurements for all cannons. This gage allows a precise measurement of the distance between the lands in the bore near the start of rifling. Tube wear in this region is a fair indication of remaining tube life. Wear measurements should not be substituted for calibration, but they can be used to detect extremes in velocities within a group of weapons. However, there is little reliability in VE constructed through these extremes. Pullover gage readings can be used to group weapons initially when immediate calibration is not feasible. Changes in the readings may be used as a guide in scheduling recalibration.

★22-4. Chronograph Support

a. *Equipment.* Chronograph support to calibrate field artillery pieces is provided by ordnance teams and by teams organic to field artillery units. If chronograph support organic to the field artillery is used, it is desirable to conduct calibration in coordination with other scheduled firings so that ammunition need not be expended specifically to calibrate.

b. *Skyscreen.* The chronograph used by ordnance teams is usually the skyscreen.

(1) The skyscreen is a set of photoelectric cells which is placed along a carefully sur-

veyed base. The base is established along a prolongation of the tube. Passage of the projectile overhead changes the light intensity striking the cells which in turn activates an electric time counter. The ordnance team computes the mean developed muzzle velocity of the rounds fired from each weapon. It then compensates for the effect of nonstandard conditions to determine the muzzle velocity.

(2) When calibration is to be done by an ordnance team using skyscreen, the following procedures should be followed. A bench checked (ordnance tested) gunner's quadrant should be available and all propellant thermometers to be used should be calibrated. A firing point must be chosen with no trees, a minimum of underbrush, and as level as possible out to 200 meters in front of the weapon. An area approximately 30 meters behind and slightly to one side of the firing point must be set aside for the calibration van. A traffic pattern must be laid out and enforced so that no traffic crosses the calibration team's cables between the van and the screens. A deflection and quadrant elevation are chosen so that the rounds fall within safety limits. If a fall of shot calibration is desired, the deflection and quadrant elevation must be such that all observers can see the bursts. The selection of suitable firing data is important since once the screens are emplaced, even a small change in firing data requires repositioning of the screens which takes as much time as the original positioning.

(3) When calibrating more than one weapon, it is preferable to fire all pieces successively from the same position while the skyscreens remain in place. The first piece to be calibrated is laid and its position staked so that subsequent pieces will stop on the same spot. The calibration team then emplaces the skyscreens by sighting through the tube. Once the skyscreens are emplaced, there is no need to lay each subsequent piece by aiming circle. Each weapon pulls into the position marked by the stake, the tube is laid by sighting through it directly over the screens, a sight picture is taken, and aiming post displacement is correc-

ted. Since the tube is centered over the skyscreens, which have not been moved, it is laid on the selected azimuth and is therefore, safe. Log books for each weapon are delivered to the ordnance team as the piece comes to the firing point.

c. *Ammunition.* Muzzle velocity is a measure of the shooting strength of a weapon, ammunition and charge combination. Sufficient amounts of the same lot of propellant and projectile must be available for each piece to be calibrated in order to obtain a valid sampling. It is recommended that, for each charge, 10 rounds per light or medium piece and 8 rounds per heavy piece be fired during the calibration. This includes two rounds for conditioning the piece (warming rounds), the results of which may be discarded if they result in erratic readings. The calibration can be conducted with fewer rounds consistent with ammunition allowances but with some sacrifice of accuracy and overall reliability.

d. *Radar Chronograph, M36.* Chronographs of the radar doppler type are organic to field artillery units. They are more flexible than skyscreen equipment and are capable of day and night operation. The M36 is ideally suited for use during tactical operations. Accuracy attained with the M36 chronograph is equal to the accuracy attained with the skyscreen.

(1) The radar doppler chronograph organic to field artillery units is the Radar Chronograph Set M36. It is a portable electronic instrument which measures weapon/projectile velocities ranging from 75 to 1,860 meters per second. It operates on the basic principle that the frequency of the transmitted radio waves will change when reflected from a moving projectile. The difference in frequencies between the transmitted and received signals is measured and converted by electronic circuitry to an indicated velocity which is read directly in meters per second. The chronograph team adjusts the indicated velocity to a muzzle velocity under standard conditions of gravity, surface air density, propellant temperature, and projectile weight. The M36 operates from a vehicle or ground mount to the side of the piece. The M36 is laid parallel to the weapon being calibrated in the normal manner; i.e., aiming circle,

reciprocal lay by the piece, or common aiming point. The chronograph can follow changes in direction and elevation as fast as the piece can be laid. This speed and lack of intensive preparation permits calibration whenever firing is conducted and an M36 chronograph is available. For a more detailed discussion of the M36 see TM 9-1290-325-12/1 and -12/2.

(2) The muzzle velocity of a given weapon varies from charge to charge. The only method of determining the muzzle velocity precisely with any particular charge is to calibrate with that charge. The unit should ascertain that a sufficiently large number of a propellant lot is available in order to get a maximum value out of the calibration. Tubes must be clean and dry to eliminate velocity trends due to oil and dirt.

(3) After each round fired, the M36 displays a readout which is the indicated velocity of the projectile at some point along the trajectory as determined by the delay selector switch. The readout velocity must be corrected for all nonstandard conditions except those of tube wear and propellant efficiency. The corrected velocity is the muzzle velocity which the weapon achieves with the propellant lot and charge used for the calibration. Readout velocities are converted to muzzle velocities under standard conditions by means of extrapolation tables. Computations are made as shown at figure 22-0.1. When FADAC has been programmed with the appropriate tape, it will perform the necessary extrapolation and display the corrected muzzle velocity.

(4) Assume that a 155-mm howitzer, M109 is being calibrated. The tube is considered conditioned by virtue of recently having fired a mission with the same charge so that warming rounds are not required.

(a) *Known data.*

Unit: Battery A, 5th Battalion, 19th Artillery
 Date: 18 January
 Time: 0930 hours
 M36 Serial No: 37
 Tube Serial No. 15215
 Charge: 5 GB (standard MV, 375 m/s)
 Projectile and Weight: HE, 5 sq
 Propellant Lot: BAJ-63320
 Propellant Temperature: 66°F

Delay Position: 3

Velocity Position: 2

Surface Air Density (provided by the met station hourly on request): 0900 hours 93.9% 1000 hours 94.3%

★(b) Quadrant elevations fired during a mission and indicated readout velocities are:

Rd No	QE	Ind Vel (m/s)
1	348	361.3
2	384	361.7
3	362	361.5
4	378	361.7
5	372	362.7
6	369	362.3

(c) Solution.

1. Enter known data on form.

2. Interpolate for the percent air density at the time of calibration (0930 hours).

$$\frac{94.3\% + 93.9\%}{2} = 94.1\%$$

★ 3. Enter table A (table 22-1). Delay Position: 3, charge 5 chronograph readout velocity 350.0 to 363.7 and determine the following:

(a) Readout time delay correction (column 3): +4.3.

(b) Air density variation from standard (94.1% — 100% = decrease 5.9%) times unit correction (column 4) (5.9 x (—0.03) = —0.177) = —0.2.

(c) Projectile weight variation from standard (5 sq — 4 sq = increase 1 sq) times unit correction (column 6) (1 x (—0.04)) = 0.

4. Enter table B (table 22-2) chronograph velocity corrections for weapon quadrant elevation, and opposite each QE fired, record the readout velocity correction:

QE	Readout velocity correction
348	—0.2
384	0.0
362	—0.1
378	—0.1
372	—0.1
369	—0.1

5. Algebraically add the delay correction, air density correction, weight correction, and readout velocity correction for each round and record as the total correction (see fig 22-0.1).

6. Add the total correction for each round to the indicated muzzle velocity of each round to determine the adjusted muzzle velocity (fig 22-0.1). (The values computed in 5 above correct the velocities of the projectiles from the point of

measurement back to the muzzle. They do not correct for the internal effects of nonstandard projectile weight or propellant temperature).

★ 7. Enter table C (table 22-3) Calibration Adjustments for Nonstandard Propellant Temperature. For charge 5 GB and propellant temperature 66° F interpolate to obtain the velocity correction:

$$10 \left[\begin{array}{c} 70^\circ \\ 66^\circ \\ 60^\circ \end{array} \right]_6 \quad X \quad \left[\begin{array}{c} 0 \\ ? \\ +0.5 \end{array} \right]_{-0.5}$$

$$\frac{6}{10} = \frac{X}{0.5}$$

$$X = -0.3$$

$$? = +0.5 + (-0.3) = +0.2$$

8. Enter table D (table 22-4) Calibration Adjustments for Projectile Weight. At charge 5 GB, muzzle velocities as computed in 6 above (353.0 to 372.5), obtain the correction for projectile weight (+1.9).

9. Algebraically add the corrections for propellant temperature and projectile weight to obtain the total correction (fig. 22-0.1).

10. Algebraically add the adjusted muzzle velocities to the total corrections to determine the final muzzle velocities (fig. 22-0.1).

★ (d) If a muzzle velocity variation (MVV) is desired, the final muzzle velocities are averaged and the standard muzzle velocity (375 m/s) subtracted from the average muzzle velocity.

$$\text{Avg MV} = \frac{367.3 + 367.9 + 367.6 + 367.8 + 368.8 + 368.4}{6}$$

$$= 368.0$$

$$\text{MV} = 368.0 - 375.0 = -7.0 \text{ m/s}$$

22-5. Application of Muzzle Velocity

a. *Grouping of Weapons.* Weapons are grouped by muzzle velocity so that each firing battery has pieces which are as close to each other in shooting strength as the situation permits. In some instances in which one or more pieces vary considerably in MV, the next higher artillery headquarters may arrange for appropriate transfer of weapons between battalions having the same caliber.

b. *Selection of Standard Piece.* Once grouping within the battalion has been accomplished, each battery selects a weapon as the base piece. The base piece is the piece nearest in muzzle velocity

to the average of the battery and such that the greatest number of other battery pieces are within 1.5 meters per second in muzzle velocity.

Table 22-1

Projectile, 155-mm, HE, M107

TABLE A
Chronograph Velocity Corrections

1	2		3	4	5	6	7	8
Charge	Chronograph Readout Velocity		Readout Velocity Correction for					
			Delay Time	1% Air Density		Proj Weight		M126 Howitzer
	from	to		decrease	increase	decrease	increase	
no.	m/s		m/s	m/s	m/s	m/s	m/s	m/s
1-2	140.0	241.7	1.3	-.00	+.00	+.00	-.00	-0.0
3-4	242.0	300.0	1.7	-.01	+.01	+.01	-.01	-0.1
4	300.3	318.3	2.0	-.01	+.01	+.02	-.02	-0.2
4-5	318.7	326.3	2.3	-.02	+.02	+.02	-.02	-0.2
	326.7	331.0	2.7	-.02	+.02	+.03	-.03	-0.2
5	331.3	334.3	3.0	-.02	+.02	+.03	-.03	-0.2
	334.7	337.3	3.3	-.03	+.03	+.03	-.03	-0.3
	337.7	341.3	3.7	-.03	+.03	+.03	-.03	-0.3
	341.7	349.7	4.0	-.03	+.03	+.03	-.03	-0.3
	350.0	363.7	4.3	-.03	+.03	+.04	-.04	-0.3
	364.0	380.0	4.7	-.04	+.04	+.04	-.04	-0.3
6	380.3	399.3	5.0	-.04	+.04	+.04	-.04	-0.2
	399.7	423.3	5.3	-.04	+.04	+.05	-.05	-0.2
	423.7	443.7	5.7	-.05	+.05	+.05	-.05	-0.1
7	444.0	463.7	6.0	-.05	+.05	+.06	-.06	-0.1
	464.0	483.7	6.3	-.05	+.05	+.06	-.06	-0.1
	484.0	503.7	6.7	-.06	+.06	+.06	-.06	-0.1
	504.0	524.0	7.0	-.06	+.06	+.07	-.07	-0.1
	524.3	544.0	7.3	-.06	+.06	+.07	-.07	-0.1
	544.3	564.0	7.7	-.07	+.07	+.08	-.08	-0.1
	564.3	584.0	8.0	-.07	+.07	+.08	-.08	-0.1
	584.3	604.0	8.3	-.07	+.07	+.08	-.08	-0.1

DO NOT INTERPOLATE

Table 22-2

Projectile, 155-mm, HE, M107

TABLE B
Chronograph Velocity Corrections
for
Weapon Quadrant Elevation

Quadrant elevation		Readout velocity correction
From	To	
mil		m/s
00.0	30.9	-1.2
31.0	62.3	-1.1
62.4	93.7	-1.0
93.8	125.2	-0.9
125.3	156.8	-0.8
156.9	188.5	-0.7
188.6	220.3	-0.6
220.4	252.3	-0.5
252.4	284.5	-0.4
284.6	317.0	-0.3
317.1	349.9	-0.2
350.0	383.1	-0.1
383.2	416.7	0.0
416.8	450.7	+0.1
450.8	485.3	+0.2
485.4	520.6	+0.3
520.7	556.6	+0.4
556.7	593.4	+0.5
593.5	631.0	+0.6
631.1	669.6	+0.7
669.7	709.3	+0.8
709.4	750.3	+0.9
750.4	792.9	+1.0
793.0	837.3	+1.1
837.4	883.8	+1.2
883.9	933.0	+1.3
933.1	985.6	+1.4
985.7	1042.4	+1.5
1042.5	1104.8	+1.6
1104.9	1175.6	+1.7
1175.7	1260.0	+1.8
1260.1	1300.0	+1.9

DO NOT INTERPOLATE

Table 22-3

Projectile, 155-mm, HE, M107

TABLE C

Calibration Adjustments
for

Nonstandard Propellant Temperature (70° F or 21.1° C is standard)

Propellant Temperature		Velocity Corrections in m/s for Propelling Charge									
		M3 (GREEN BAG) at Charge					M4A1 (WHITE BAG) at Charge				
° F	° C	1	2	3	4	5	3	4	5	6	7
-50	-45.6	+ 4.8	+ 5.2	+ 5.5	+ 5.8	+ 5.7	+ 9.8	+ 11.6	+ 14.2	+ 17.7	+ 21.1
-40	-40.0	+ 4.2	+ 4.6	+ 5.0	+ 5.2	+ 5.2	+ 8.8	+ 10.5	+ 13.0	+ 16.2	+ 19.3
-30	-34.4	+ 3.7	+ 4.1	+ 4.5	+ 4.7	+ 4.8	+ 7.8	+ 9.4	+ 11.7	+ 14.7	+ 17.5
-20	-28.9	+ 3.3	+ 3.6	+ 4.0	+ 4.2	+ 4.3	+ 6.8	+ 8.4	+ 10.5	+ 13.2	+ 15.6
-10	-23.3	+2.8	+ 3.2	+ 3.5	+ 3.8	+ 3.8	+ 5.9	+ 7.3	+ 9.3	+ 11.7	+ 13.8
0	-17.8	+ 2.4	+ 2.7	+ 3.0	+ 3.3	+ 3.4	+ 5.0	+ 6.3	+ 8.1	+ 10.2	+ 12.1
10	-12.2	+ 2.0	+ 2.3	+ 2.5	+ 2.8	+ 2.9	+ 4.2	+ 5.3	+ 6.9	+ 8.7	+ 10.3
20	- 6.7	+ 1.6	+ 1.8	+ 2.1	+ 2.3	+ 2.3	+ 3.4	+ 4.4	+ 5.7	+ 7.3	+ 8.5
30	- 1.1	+ 1.2	+ 1.4	+ 1.6	+ 1.8	+ 1.9	+ 2.6	+ 3.5	+ 4.5	+ 5.8	+ 6.8
40	4.4	+ 0.9	+ 1.0	+ 1.2	+ 1.4	+ 1.5	+ 1.9	+ 2.6	+ 3.4	+ 4.3	+ 5.1
50	10.0	+ 0.6	+ 0.7	+ 0.8	+ 0.9	+ 1.0	+ 1.3	+ 1.7	+ 2.2	+ 2.9	+ 3.4
60	15.6	+ 0.3	+ 0.3	+ 0.4	+ 0.4	+ 0.5	+ 0.6	+ 0.8	+ 1.1	+ 1.4	+ 1.7
70	21.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
80	26.7	-0.2	-0.3	-0.4	-0.4	-0.5	-0.6	- 0.8	- 1.1	- 1.4	- 1.7
90	32.2	-0.5	-0.6	-0.7	-0.9	-1.0	-1.1	- 1.6	- 2.2	- 2.9	- 3.3
100	37.8	-0.7	-0.9	-1.1	-1.3	-1.5	-1.6	- 2.3	- 3.3	- 4.3	- 4.9
110	43.3	-0.8	-1.1	-1.4	-1.7	-2.0	-2.0	- 3.1	- 4.3	- 5.7	- 6.6
120	48.9	-1.0	-1.4	-1.8	-2.2	-2.5	-2.4	- 3.8	- 5.4	- 7.1	- 8.2
130	54.4	-1.1	-1.6	-2.1	-2.6	-3.0	-2.8	- 4.4	- 6.4	- 8.5	- 9.7

INTERPOLATE TO 1° F and 0.1° C

Table 22-4

Projectile, 155-mm, HE, M107

TABLE D
Calibration Adjustments for
Projectile Weight (Four Square is standard)

GREEN BAG			Muzzle Velocity Correction for change in Projectile Weight ☐	WHITE BAG			
Charge M3	Muzzle Velocity			Muzzle Velocity			Charge M4A1
	from	to		from	to		
	m/s		m/s	m/s			
1	150.0	159.6	0.8			3	
	159.7	178.8	0.9				
1-2	178.9	198.0	1.0	248.5	274.5	4	
	198.1	217.2	1.1	274.6	300.0		
2-3	217.3	236.4	1.2	300.1	324.2	5	
	236.5	255.7	1.3	324.3	346.9		
4	255.8	275.0	1.4	347.0	367.8	6	
	275.1	294.4	1.5	367.9	387.2		
5	294.5	313.9	1.6	387.3	405.5	7	
	314.0	333.4	1.7	405.6	423.3		
	333.5	352.9	1.8	423.4	440.5		
	353.0	372.5	1.9	440.6	457.3		
	372.6	392.1	2.0	457.4	476.5		
	392.2	411.7	2.1	476.4	497.1		
	411.8	430.0	2.2	497.2	517.4		
			2.3	517.5	537.6		
			2.4	537.7	557.5		
			2.5	557.6	577.3		
			2.6	577.4	596.9		
			2.7	597.0	600.0		

Note: The correction is to be subtracted for projectiles lighter than standard;
added for those heavier.

DO NOT INTERPOLATE

M-36 CHRONOGRAPH CALIBRATION SHEET

DATE <u>18 Jun</u> TIME <u>0930</u>				M36 SER # <u>37</u>				CALIBER <u>155 M109</u>				SHELL <u>M107</u>				UNIT <u>Btry A</u>			
AD TIME <u>0900</u> , <u>93.9</u> %				VEL POS <u>2</u> DELAY <u>3</u>				WPN SER # <u></u>								5 Bn, 19 Arty			
TIME <u>1000</u> , <u>94.3</u> %				STDMV <u>375 m/s</u> CHG <u>5GB</u>				TUBE SER # <u>15215</u>				PROP LOT <u>BAJ-</u>							
RECORDER <u></u>												63320							

RDS	%AD	Q ELEV	PROJ WGT	PT	IND VEL	DELAY CORR	AD CORR	WGT CORR	QE CORR	TOTAL CORR	ADJ MV	PT	ADJ WGT	TOTAL CORR	FINAL MV	REMARKS
1	94.1	348	5 sq	66°	361.3	+4.3	-0.2	0	-0.2	+3.9	365.2	+0.2	+1.9	+2.1	367.3	
2		384			361.7				0.0	+4.1	365.8				367.9	
3		362			361.5				-0.1	+4.0	365.5				367.6	
4		378			361.7				0.1	+4.0	365.7				367.8	
5		372			362.7				-0.1	+4.0	366.7				368.8	
6		369			362.3				-0.1	+4.0	366.3				368.4	
7																
8																
9																
10																
11																
12																
13																
14																
15																
16																

Figure 22-0.1. M-36 Chronograph calibration computations.

c. Computation of Firing Data.

- (1) The average MV for each battery determined by chronograph calibration is used as an MV input to the Gun Direction Computer M18 (FADAC). For a more detailed explanation, see FM 6-3-1.
- (2) The average MV determined by chronograph calibration for each battery may be used in determining a GFT setting as outlined in paragraph 23-2. When a position VE or average VE is available from prior registrations and concurrent met messages, the VE is preferred to the MVV in making the GFT setting.

22-6. Example Problem

a. A 155-mm howitzer M109 battalion has been issued 18 weapons. Pullover gage readings provided by ordnance furnish data to permit an interim distribution of pieces to each battery. This initial distribution is temporary, since the wear measurement is only a fair indication of muzzle velocity and is used only until calibration is accomplished.

b. An ordnance calibration team and sufficient ammunition of one lot are arranged for and the decision is made to calibrate all weapons. The S3 determines that charge 4 green bag provides the best range coverage for this and future firings.

c. All weapons of the battalion are calibrated, and the readings obtained for piece number one of Battery A are as follows:

Round number	Reported MV (m/s)
1 -----	311.7
2 -----	315.9
3 -----	316.0
4 -----	317.2
5 -----	316.6
6 -----	316.1
7 -----	318.8
8 -----	317.3
9 -----	316.5
10 -----	315.7

- (1) Rounds number 1 and 7 are discarded as erratic and the remaining eight rounds are retained. Round number 2 is used, even though it is a warming round, since it appears to be consistent with the other rounds. The readings of the eight rounds are averaged, and the result is the MV for this weapon and ammunition lot.

- (2) The muzzle velocities are computed in the same manner for the other 17 pieces in the battalion and the results tabulated.

Battery	Piece number	MV(m/s)
A-----	1	316.4
	2	311.5
	3	312.7
	4	314.2
	5	315.7
	6	314.6
B-----	1	310.4
	2	307.3
	3	309.3
	4	308.5
	5	313.6
	6	309.7
C-----	1	304.1
	2	309.1
	3	306.8
	4	305.0
	5	309.0
	6	306.4

- (3) The weapons are listed in order of decreasing muzzle velocity.

Piece number	MV (m/s)
A1 -----	316.4
A5 -----	315.7
A6 -----	314.6
A4 -----	314.2
B5 -----	313.6
A3 -----	312.7
A2 -----	311.5
B1 -----	310.4
B6 -----	309.7
B3 -----	309.3
C2 -----	309.1
C5 -----	309.0
B4 -----	308.5
B2 -----	307.3
C3 -----	306.8
C6 -----	306.4
C4 -----	305.0
C1 -----	304.1

- (4) The final muzzle velocities are the basis for regrouping the weapons. Suppose that the unit SOP requires that long-shooting weapons be in Battery A, medium-shooting weapons be in Battery B, and short-shooting weapons be in Battery C. The weapons in (3) above are regrouped by placing the first six (longest shooting) in Battery A, the next six in Battery B, and the last six in Battery C. Most of the weapons were properly grouped on the basis of pullover gage readings but some

transferring was required. Battery A weapons now consist of the following:

Piece number	MV (m/s)
A1 -----	316.4
A2 (formerly B5) -----	313.6
A3 (formerly A6) -----	314.6
A4 -----	314.2
A5 -----	315.7
A6 (formerly A3) -----	312.7

- (5) Piece number A4 is designated the base piece. It is close to the average MV of the battery, and this arrangement requires that only A1 have special corrections applied since it is the only weapon the MV of which varies by more than 1.5 m/s from the base piece. The exchange of piece numbers between A3 and A6 as shown is not absolutely necessary. It is done in this

case to show that the weapon with MV 314.6 (regardless of its number) is in the center platoon with A4 because it is closest in shooting strength and provides a close grouping in the adjustment phase of observer-adjust missions.

22-7. Records

A record of each lot number of ammunition and associated muzzle velocity could be an aid to the operations officer. It is possible that the same lot could be issued after an interval of time has passed, and a knowledge of the performance of the lot may eliminate the need for calibration. This is particularly true when the unit does not fire sufficient full service rounds to materially decrease the shooting strengths of its pieces.

Section III. FALL-OF-SHOT COMPARATIVE CALIBRATION

22-8. Preliminary Considerations

a. General. Comparative calibration is based on the premise that the total effects of nonstandard conditions (except velocity deviation from standard) have equal influence on the locations of the mean point of impact. This premise assumes that the difference in range between MPI's is an indication of the difference in velocity. This assumption is valid only within certain limits. For example, it does not mean that weather conditions can be ignored. Relatively stable wind is a condition which must be sought for calibration; and a fall-of-shot calibration, either comparative or absolute, should not be attempted during the passage of a weather front.

b. Ammunition. Regardless of recent improvements made in the manufacture of ammunition, there remains a significant difference in performance between lots with respect to propellant velocity. It is recommended that 10 rounds per light or medium piece and 8 rounds per heavy piece be fired during the calibration; this includes 2 rounds for conditioning the piece (warming rounds). The calibration can be conducted with fewer rounds consistent with ammunition allowances but with some sacrifice of overall reliability. The propellant and the projectile must each be of a single lot; however, if the fuzes are not available in a single lot, it is permissible, to calibrate with fuzes of the same type from different lots.

c. Optimum Charge. The VE (or MVV) of a given weapon will vary from charge to charge. The only method of determining the VE (or MVV) precisely with any particular charge is to calibrate with that charge. However, it is rarely possible to calibrate all weapons with all charges. Usually, calibration is accomplished with only one charge, and, hence, it is necessary to select the charge which will cover the ranges most frequently fired. Grouping of weapons must be based on calibration with one charge. Comparative calibration data determined with one charge work fairly well as a basis for individual piece corrections for all other charges for howitzers but not too well for guns. Absolute calibration data are valid only for the specific charge fired.

d. Quadrant Elevation. When fall-of-shot calibration is being conducted, the weapon should be calibrated at a quadrant elevation between 240 and 460 mils. A low quadrant elevation minimizes the effect of nonvelocity elements absorbed into the velocity error.

e. Emplacement of Weapons. The weapons to be calibrated should be employed in a level position area with about 2 feet between trails of adjacent pieces when spread. Cant must be eliminated. The weapons may be laid for direction by any of the methods described in chapter 4. The target area should be level and, if at all possible should be at about the same altitude as the position area. The

weapons should be located to fifth order survey accuracy (FM 6-2).

f. Observation. If possible, coordination should be effected with the target acquisition battalion which will normally provide the required flash base from which the mean point of impact achieved by each weapon is determined. Organic observation may be used, provided the observers are trained and equipped to provide the high degree of accuracy required for fall-of-shot calibration. When organic observation is used, four OP's should be installed, each equipped with a battery commander's telescope or aiming circle. The OP's must be located to a survey accuracy of not less than 1:1,000 (fifth order) and tied to a common reference point of the same accuracy (FM 6-2). Each observer records direction and vertical angle for each round. Care must be exercised in recording so that rounds can be related to their respective pieces. An erratic round can be defined as one which falls more than 4 range probable errors away from the mean point of impact of the rounds fired. A round which obviously does not fit the pattern of the remaining rounds should be classified as erratic and should not be included in the location of the mean point of impact. This necessitates a quick check of directions recorded by the two flank observers before releasing a piece from the calibration site. If, for the same round, both of these observers recorded a direction quite different from all others in that group, then an additional round should be fired from that piece. The decision to fire additional rounds is made by the officer in charge.

g. Accuracy. To insure maximum accuracy, all personnel should be briefed on the importance of the calibration. A reliable system of communications and exchange of commands, data, and information should be worked out. And SOP should be developed for the conduct of firing. It is especially important that bubbles are centered exactly before each round is fired. The pieces should be serviced and checked to insure that they are in proper firing condition. A bench-checked (ordnance-tested) gunner's quadrant should be used on all pieces. At least one calibrated powder thermometer per piece should be obtained before the firing.

22-9. Conduct of Firing

a. Each piece is placed over its surveyed stake. Trunnions are leveled and the pieces are bore-

sighted and then laid. Tubes must be cleansed of all oil film and then dried.

b. Orienting data (direction and vertical angle to desired MPI) for each OP is determined and announced to the respective observers.

c. Chart data from the center of the position area to the desired point of impact are measured from a map. A common deflection and quadrant elevation is determined and is used for all pieces throughout the firing. Fuze quick is always used for calibration.

d. Ammunition should be prepared sufficiently in advance of firing to assure uniform weather conditioning. Propellant temperatures of at least four rounds at each piece are measured and recorded immediately prior to firing.

e. Observers are alerted before firing is begun. For each round fired, the number of the piece firing and SHOT are announced when the piece is fired. SPLASH is announced 5 seconds before impact.

f. Each piece is laid for quadrant elevation with the same gunner's quadrant. Battery right (left) is used in order to equalize the weather conditions under which each piece is fired. Sufficient time between rounds must be allowed to enable the observers to locate the round, record the data for that round, and change the orienting data for the next round if necessary. (About 30 seconds is sufficient for the average crew.)

g. The first two rounds from each piece are conditioning rounds but the observers should pick up, report, and record data as a check of the system and procedures.

h. Firing should be completed as rapidly as possible. If a piece misfires, that piece is called out, the observers are notified, and firing of the other pieces is continued.

i. Before the pieces are released, a check with the observers should be made to make sure that data for all rounds have been recorded and to see if any rounds were erratic. Refiring should be accomplished immediately if any rounds were erratic or if the observers missed any rounds.

22-10. Determination of Range to and Altitude of the Mean Point of Impact for Each Piece

a. When the target acquisition battalion provides the flash base, it furnishes the coordinates and altitude of the mean point of impact for each

piece. When the unit provides its own observations, the S3 must examine the observer's recorded data in order to detect erratic rounds and questionable observer data.

b. After the conditioning rounds and erratic rounds have been deleted, the procedure for determining the MPI range for each piece is as follows:

- (1) Compute the average azimuth from each OP for each piece.
- (2) Form three target area bases by using selected pairs of OP's (fig. 22-1).
- (3) Compute three sets of grid coordinates for each mean point of impact, one from each of the three bases.
- (4) If there is an appreciable difference in the three sets of coordinates, (20 meters or more radially), perform a graphic check (*d* below).
- (5) Average the three sets of coordinates to arrive at the mean MPI location.
- (6) Using the coordinates of the pieces and their respective MPI location, compute the range to the mean point of impact.

c. The altitude of the MPI is determined by computing the altitude of the MPI from each OP and averaging the four altitudes to determine the mean altitude. (If accurate maps are available, the MPI altitude may be measured from the map.)

d. If survey, observer orientation, and observer readings are correct, all rays, as plotted from their respective OP's, will theoretically intersect at a common point. Normally, however, the rays, either for a single round or a mean point of impact, will not intersect but will form a polygon of error. If observer data appear to be of questionable accuracy, a graphical check on the magnitude and nature of the polygon of error will detect it. The graphical check is accomplished by plotting all OP's on a gridded sheet to a scale of 1:6,250 and plotting the azimuth of the round or mean point of impact in question as rays from the respective observation posts. If the graphical check indicates that only one observer is appreciably in error, these data are deleted and the data of the other three observers are used. If more than one observer is in error, then it is best to use the data from all observers as being equally valid because it is not possible to pick out the specific observers at fault. The size of the polygon of error accepted is a good measure of the accuracy of resultant

range data and, hence, the calibration itself. The smaller the polygon, the more accurate the calibration. A graphical check should be made on the common reference point before firing begins.

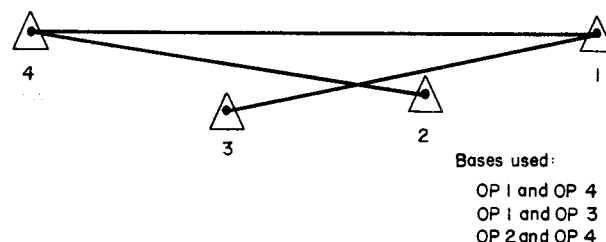


Figure 22-1. Target area bases.

22-11. Adjustment of Ranges for Differences in Altitude

a. A valid comparison of the ranges achieved by the pieces being calibrated could be obtained if all pieces were at the same altitude and if all mean points of impact were at the same altitude. The pieces can be established at the same altitude by selecting a level position area. However, the mean points of impact cannot be determined beforehand, even though a relatively level impact area is selected, because the altitudes of the mean points of impact may vary. Therefore, to obtain a valid comparison of the ranges achieved by *each piece*, it is necessary to correct the measured ranges to the ranges that would have been achieved had all rounds landed at a common altitude.

b. The procedure for correcting the measured ranges for differences in altitudes of the MPI is as follows:

- (1) Select a reference altitude. This altitude may be any convenient altitude. The lowest MPI altitude is commonly used as a reference altitude.
- (2) Subtract the reference altitude from the altitude of the mean point of impact.
- (3) Multiply the difference in altitude by the cotangent of the angle of fall. (The cotangent of the angle of fall is determined from the Supplementary Data table (table G) at the measured range to the MPI rounded to the nearest 100 meters.) If the altitude of the MPI is greater (less) than the reference altitude, the sign of the correction is plus (minus).

- (4) Add the range correction determined in (3) above to the measured range to determine the corrected range.

22-12. Selection of the Standard Piece

In a comparative calibration, the piece that achieved the longest corrected range is chosen as the standard piece. Its corrected range is the standard with which the corrected range of the other pieces is compared. The comparative VE assigned to the standard piece is zero meters per second.

22-13. Determination of Comparative Velocity Error

The procedure for determining the comparative VE of a piece is as follows:

a. Determine the difference between the corrected range of the piece in question and the corrected range of the standard piece.

b. Enter the Ground Data table (table F) at the corrected range (rounded to the nearest 100 meters) of the piece in question. Determine the correction for *decrease* in muzzle velocity of 1 meter per second.

c. Determine the VE by dividing the difference in range (a above) by the muzzle velocity unit correction (b above). The sign of the comparative VE is always *minus* if the longest shooting piece is the standard.

22-14. Correction of Velocity Error for Propellant Temperature Variations

A valid comparative VE can be determined only if all weapons fire ammunition with the same

propellant temperature. Precautions should be taken to keep all propellants at the same temperature. If there is any variation in the average propellant temperatures of the individual weapons, the comparative VE's determined (para 22-12) must be corrected. The final comparative VE of a particular piece is the VE that would have been attained if the ammunition fired by that weapon had the same propellant temperature as the ammunition of the standard piece. The procedure for correcting the VE for propellant temperature variations is as follows:

a. Enter the Propellant Temperature table (table E) and determine the change to muzzle velocity for propellant temperature for all pieces.

b. To determine the correction to VE, subtract (algebraically) the change to muzzle velocity for propellant temperature of each piece from that of the standard piece.

c. To determine the final comparative VE's, add the corrections (b above) to the respective VE's determined as prescribed in paragraph 22-13.

22-15. Example Problem

A 155-mm howitzer M109 battalion has completed firing a fall-of-shot comparative calibration with charge 7, quadrant elevation 310. All pieces were at the same altitude. After the range and altitude of each MPI have been computed, the following data are available (data for only four pieces are shown):

Piece number	Computed range (meters)	Altitude of MPI (meters)	Average propellant temperature (Fahrenheit)
1-----	9665	320	83°
2-----	9710	316	80°
3-----	9790	321	80°
4-----	9610	325	78°

a. Determine the corrected range for each piece by correcting for differences in altitudes of mean points of impact. The lowest MPI altitude (316 meters) is selected as the reference altitude.

Piece number	Computed range (meters)	Altitude of MPI (meters)	Difference in altitude (meters)	Cotangent of angle of fall	Range correction (meters)	Corrected range (meters)
1-----	9665	320	+4	2.1	+8	9673
2-----	9710	316	0	2.1	0	9710
3-----	9790	321	+5	2.1	+10	9800
4-----	9610	325	+9	2.2	+20	9630

- b. Piece number 3 is selected as the standard piece because its corrected range (9800) is the greatest.
c. The VE's are then determined.

Piece number	Corrected range	Difference from std rg	MV unit correction	VE
1-----	9673	-127	21.1	-6.0 m/s
2-----	9710	-90	21.1	-4.3 m/s
3-----	9800	0	-----	0 m/s
4-----	9630	-170	21.0	-8.1 m/s

d. The final VE's are determined by correcting for differences in propellant temperature (PT) between the standard piece and all other pieces.

Piece number	PT	Change to MV for PT	Correction to VE for PT	VE	Final VE
1-----	83° F	+2.2	-0.5	-6.0	-6.5 m/s
2-----	80° F	+1.7	0	-4.3	-4.3 m/s
3-----	80° F	+1.7	0	0	0 m/s
4-----	78° F	+1.4	+0.3	-8.1	-7.8 m/s

22-16. Comparative Calibration by Battery

a. At times it may be necessary to conduct a comparative calibration with each battery calibrating on a different day rather than the whole battalion calibrating at one time.

b. When comparative calibration is conducted at battery level, the procedures in (1) through (3) below are used to convert the separate calibrations to a common calibration for the battalion. This calibration is necessary in order to properly group the weapons within the battalion.

- (1) The first battery to calibrate its weapons also calibrates one piece from each of the other two batteries. These pieces will be used later with their respective batteries as control pieces.
- (2) Each separate calibration is conducted and computed as outlined in paragraphs 22-8 through 22-14.
- (3) When all batteries have been calibrated, different sets of data are adjusted to a common level by applying a correction to the VE's of the second and third batteries to calibrate. The correction is the number of meters per second required to bring the VE of the control piece when calibrated with its own battery to the VE of the control piece when calibrated with the first battery.

c. An example of adjusting separate battery calibrations to a common level is given in (1) through (6) below.

- (1) Respective battery VE's (Battery A is calibrated first; Battery B, second; and Battery C, third) are as follows:

A		B		C	
Weapon	VE	Weapon	VE	Weapon	VE
A1-----	0	B1*	-2.4	C1**	-1.5
A2-----	-1.2	B2	-0.9	C2	-0.3
A3-----	-2.1	B3	0	C3	-1.8
A4-----	-2.4	B4	-1.5	C4	-2.1
A5-----	-3.7	B5	-2.7	C5	0
A6-----	-4.6	B6	-3.4	C6	-1.2
B1*-----	-0.6				
C1**-----	-2.7				

*Battery B control weapon.

**Battery C control weapon.

- (2) In order to adjust the VE's of Battery B, note that +1.8 m/s must be added to the VE for B1 to bring it to the VE obtained with Battery A; hence, +1.8 m/s must be added to all VE's in Battery B.
- (3) Similarly, for Battery C an additional -1.2 m/s is required to bring the VE of C1 to the VE it obtained with Battery A; hence, -1.2 m/s must be applied to all VE's in Battery C.
- (4) By using these correction factors ((2) and (3) above), the calibration data can be rewritten (adjusted to a common level) as follows:

A		B		C	
Weapon	VE	Weapon	VE	Weapon	VE
A1-----	0	B1	-0.6	C1	-2.7
A2-----	-1.2	B2	+0.9	C2	-1.5
A3-----	-2.1	B3	+1.8	C3	-3.0
A4-----	-2.4	B4	+0.3	C4	-3.3
A5-----	-3.7	B5	-0.9	C5	-1.2
A6-----	-4.6	B6	-1.6	C6	-2.4

- (5) The weapons can now be listed in order of decreasing shooting strength and the VE's adjusted so that the longest shooting weapon has a VE of 0; the correction required to bring the longest shooting piece to 0 must be applied similarly to all weapons.

Order of strength	First adjusted VE	Final adjusted VE
B3-----	+1.8	0
B2-----	+0.9	-0.9
B4-----	+0.3	-1.5
A1-----	0	-1.8
B1-----	-0.6	-2.4
B5-----	-0.9	-2.7
A2-----	-1.2	-3.0
C5-----	-1.2	-3.0

Order of strength	First adjusted VE	Final adjusted VE
C2-----	-1.5	-3.3
B6-----	-1.6	-3.4
A3-----	-2.1	-3.9
A4-----	-2.4	-4.2
C6-----	-2.4	-4.2
C1-----	-2.7	-4.5
C3-----	-3.0	-4.8
C4-----	-3.3	-5.1
A5-----	-3.7	-5.5
A6-----	-4.6	-6.4

- (6) The final adjusted VE's are the basis for regrouping the weapons. They represent comparative calibration equal to a battalion calibration.

Section IV. FALL-OF-SHOT ABSOLUTE CALIBRATION

22-17. Preliminary Considerations

a. Nonstandard Conditions. The effects of muzzle velocity must be isolated from the effects of all other nonstandard conditions; however, certain deviations from this basic requirement are accepted in present techniques and will be noted. Careful preparation must be made for obtaining and using met data. Coordination between the officer in charge of the calibration and the officer in charge of the met station is essential. The met station is ideally located at a point between the weapon and target and at such a position that the balloon would pass as near the summit of the trajectory as possible. The time of the met passage and the time of firing should be coordinated.

b. Selecting the Quadrant Elevation. The QE fired should be selected so that the maximum ordinate will be equal to an altitude of a whole line number of the met message. The method of bringing an acceptable QE (240 to 460 mils) into agreement with a line number of the met message involves the use of the Supplementary Data table of the firing table. The following example illustrates the method of selecting the QE to be fired in calibrating a 155-mm howitzer M109 with charge 5 green bag:

Altitude of met line numbers	
Line 2-----	500 meters.
Line 3-----	1,000 meters.
Line 4-----	1,500 meters.
Line 5-----	2,000 meters.

From the Supplementary Data table, a maximum ordinate of 500 meters results in a horizontal range of approximately 6,000 meters. The quadrant elevations for ranges in the vicinity of 6,000 meters are in the vicinity of 296 mils, a good QE for calibration. The range corresponding to a maximum ordinate of 500 meters is 6,037 meters. The corresponding QE is 298.3 mils. For convenience, this QE can be rounded to 300 mils for firing the calibration.

c. Selecting Pieces for Calibration. It is sometimes desirable to bring only a limited number of pieces into a state of absolute calibration. Preferably, three pieces per battalion are selected, although one is sufficient. The base piece, if determined, or a piece with average wear measurement within each battery should be selected. If comparative calibration data are known or later determined, all pieces can be brought into an acceptable state of absolute calibration. An example problem is shown in paragraph 22-20a.

d. Other Considerations. Except as stated herein, preliminary considerations are the same as those for comparative calibration.

22-18. Conduct of Firing (Absolute Calibration)

An absolute calibration is conducted in the same manner as a comparative calibration, except that fire by battery right (left) is not used. Each piece will complete the firing of its MPI before the next

piece fires. Each MPI should be fired as rapidly as possible consistent with the capabilities of the weapon and personnel involved in order to minimize range effects due to changes in weather. Speed should not, however, take precedence over accuracy.

22-19. Computation of Absolute Velocity Error

a. To compute the VE, first locate the MPI for each weapon by using the method described in paragraph 22-10. Compute the developed MPI range. Compute site, using the difference in altitude between the piece and the mean point of impact. Subtract the site from the QE fired to determine the elevation fired. Enter the Ground Data table and interpolate for the range corresponding to the elevation. This is the standard horizontal range that would have been achieved if all conditions had been standard at the time of firing. Subtract the developed MPI range from the standard (firing table) range. The resultant difference in range is the range correction necessary to compensate for all nonstandard conditions at the time of firing.

b. Compute range corrections for all known nonstandard conditions, except propellant temperature, using met data taken at time of firing. All unit corrections are determined at the range (nearest 100 meters) to the mean point of impact. The line number is that corresponding to the QE fired.

c. Subtract the met range correction from the total range correction determined as described in a above. The result is the correction in meters to compensate for ΔV . Compute the ΔV by dividing the ΔV range correction by the MV unit correction (determined at MPI range). If the ΔV range correction is plus (minus), the MV unit correction is taken from the *Decrease (Increase)* column. Determine the VE by subtracting the muzzle velocity change for propellant temperature from ΔV . The propellant temperature used is the average of all propellant temperatures recorded at the piece.

Example: 155-mm howitzer M109, charge 5 green bag:

MPI range	5,630 meters.
Site	+6.4 mils.
QE fired	300 mils.
Elevation	293.6 mils (300-6.4).

The range corresponding to elevation 293.6 mils is 5,964 meters.

Total range correction to compensate for all nonstandard conditions is +334 meters (5964-5630).

Assume that a met is solved and met range corrections are determined to be +172 meters.

ΔV range correction is +162 meters (334-172).

Unit correction for muzzle velocity (*Decrease* column, range 5600) is +15.8 (meters).

$\Delta V = +162/15.8 = -10.3$ m/s.

Propellant temperature is 53° F.

Change to muzzle velocity for propellant temperature is -0.8 m/s. VE is -9.5 m/s (-10.3 - (-0.8)).

d. The VE of -9.5 m/s in the example in c above approximates absolute calibration for this weapon-ammunition combination. However, if such a calibration is conducted in conjunction with an ordnance chronograph calibration, the officer in charge should not be unduly alarmed if the muzzle velocity variation computed is of a different magnitude. Primary reasons for this difference are—

- (1) A projectile lot, which is more or less efficient in overcoming air resistance than the projectile lot used to construct the firing tables shows up as an increase or decrease in range not otherwise accounted for.
- (2) Limitations in accurately determining met data.
- (3) Limitations of computational procedures and firing tables.
- (4) Errors in survey.
- (5) Errors in the QE used (to include barrel curvature).

e. The officer in charge should examine the magnitude and sign of the differences (VE minus MVV) and recheck computations for any sample that deviates from the pattern followed by most of the weapons. In the following example, piece 4 should be rechecked:

Piece Number	VE	MVV	Difference
1	-7.3	-5.5	-1.8
2	-9.1	-7.6	-1.5
3	-6.7	-4.6	-2.1
4	-11.3	-6.4	-4.9
5	-8.2	-7.0	-1.2
6	-7.6	-6.1	-1.5

Section V. REDISTRIBUTION OF WEAPONS

22-20. Grouping of Pieces According to Velocity

a. Grouping After Calibration by Fall of Shot.

A list by tube number of all pieces calibrated, ranging in order from the strongest shooting piece to the weakest, should be prepared for grouping the pieces. These pieces should then be assigned to batteries based on their shooting strength; i.e., the strongest one-third in one battery (normally A), the weakest one-third in another battery (normally C), and the remaining one-third in the remaining battery (normally B). Within batteries, the base piece should be the piece with the shooting strength nearest the battery average. Wear among the tubes in service can be equalized by habitually assigning to the longest shooting pieces missions which require only part of the pieces of the battery. The following examples illustrate the method of grouping pieces according to shooting strength:

Tube number	VE comparative calibration	Adjustment of VE's to absolute scale	Battery***
51180.....	0	-3.4	A1.
51242.....	-0.3	-3.7	A2.
51177*.....	-0.9	-4.3	A3 (base piece).**
51359.....	-1.2	-4.6	A4.
51628.....	-1.5	-4.9	A5.
51032.....	-1.5	-4.9	A6.
51768.....	-1.8	-5.2	B1.
51535.....	-2.4	-5.8	B2.
51640.....	-3.0	-6.4	B3 (base piece).**
51819.....	-3.4	-6.8	B4.
51225.....	-3.7	-7.1	B5.
51275.....	-4.0	-7.4	B6.
51393.....	-4.3	-7.7	C1.
51410.....	-4.3	-7.7	C2.
51733.....	-4.6	-8.0	C3.
51366.....	-4.9	-8.3	C4.
51136.....	-5.8	-9.2	C5 (base piece).**
51250.....	-6.7	-10.1	C6.

*Absolute calibration performed with this tube.

**If the designation of the average piece as the base piece causes calibration corrections to be carried on one or more of the pieces, another piece may be designated as the base piece.

***Assignment to batteries only; does not imply piece numbering within batteries.

Note. When more than one weapon in a battalion is in a state of absolute calibration with the same ammunition combination, the adjustment of VE's to the absolute scale employs the mean difference between the comparative VE and respective absolute VE, as shown below:

Piece number	Comparative VE	Absolute VE	Difference
1.....	0	-3.7	-3.7
2.....	-0.3	-4.3	-4.0
3.....	-0.9	-4.3	-3.4
Mean			-3.7

Therefore, -3.7 meters per second should be applied to the comparative VE's of all weapons to adjust to the absolute scale.

b. Grouping After Calibration by Chronograph.

The results of chronograph calibration (MVV's) are absolute calibration data. These data, when available, permit the most effective grouping, and are also the basis for the most reliable corrections for variations in shooting strength between weapons. When MVV's and VE's of either the comparative or absolute type are determined concurrently, the MVV's should be used as the basis for grouping and subsequent computation of individual piece corrections.

22-21. Computation and Application of Calibration Corrections

a. Once the weapons have been calibrated and grouped, corrections must be applied to compensate for the differences in shooting strengths between the base pieces of the batteries within the battalion and for differences between the base piece and other weapons within the battery. The computation and application of these corrections are explained in chapter 23.

b. When either MVV's or VE's of the absolute type are to be used as a basis for computation in the met plus VE technique, the following factors should be considered:

- (1) When both MVV's and VE's are available from the same calibration, the VE's normally will prove more successful in present techniques. The VE's at least partly compensate for variation in projectile lot efficiency (from the firing table lot) and barrel curvature, whereas the MVV's do not.
- (2) Velocity errors are subject to errors of met data and survey. They are also subject to limitations of present computing procedures.
- (3) The MVV or VE used in this respect is valid only for the weapon-ammunition

combination for which it has been determined.

c. The following rules should be used as a guide in applying calibration data when MVV's and VE's are both available:

- (1) Muzzle velocity variations are preferred to either type of fall-of-shot calibration data for grouping pieces and computing individual piece corrections.

- (2) Velocity errors of the type obtained from registration and concurrent met are preferred to MVV's for computing corrections to firing data as in met plus VE technique.

- (3) If MVV's and comparative VE's only are available, the MVV's are preferred for all aspects of application (grouping, individual piece corrections, and corrections to firing data).

Section VI. HEAVY ARTILLERY

22-22. General

The procedures for calibrating heavy artillery, grouping the pieces, and the subsequent computation and application of calibration corrections are the same as those for light and medium artillery. However, with the 175-mm gun, loss in muzzle velocity per round fired is significant. Unless the same number of rounds is fired by all weapons of a battery, calibration data must be altered periodically. It is, therefore, necessary to maintain an accurate record of calibration data, subsequent firing, and corrections applied to calibra-

tion data. The record of firing is maintained in the Equipment Log Book on the Weapon Record Data, DA Form 2408-4. A complete record of calibration data is kept by the battery and by the battalion.

22-23. Wear Tables

Wear tables may prove helpful in filling in the gaps between calibrations. Wear tables estimate the erosion of a gun tube as a result of firing a certain number of rounds with specified charges. From this estimated erosion, the loss in muzzle velocity may be approximated.

CHAPTER 23

CALIBRATION, POSITION, AND SPECIAL CORRECTIONS

Section I. CALIBRATION CORRECTIONS

23-1. General

Calibration corrections are corrections to compensate for the variations in the shooting strengths of the pieces in a unit. Calibration corrections are used primarily—

- a. To derive GFT settings for nonregistering batteries from the registration of one battery.
- b. In combination with position corrections when special corrections are required.
- c. To correct firing data for those weapons the shooting strength of which varies by more than 1.5 meters per second from that of the base piece.

23-2. Determination of GFT Settings for Nonregistering Batteries

a. When only one battery of a battalion equipped with weapons of the same caliber is allowed to register, the GFT setting of the registering battery is used by the nonregistering batteries in the absence of any better information. If calibration VE's of the base pieces of the batteries are known, these VE's may be applied to obtain GFT settings for the nonregistering batteries which will approach the accuracy of GFT settings that would have been obtained if all batteries had registered.

b. The procedure for determining the GFT setting for a nonregistering battery is as follows:

- (1) Determine the comparative VE of the base piece of each nonregistering battery by subtracting the VE of the base piece of the registering battery from the VE of the base piece of the battery in question.

- (2) Determine a VE range correction by multiplying the comparative VE ((1) above) by the muzzle velocity unit correction cor-

responding to the entry range for the registering battery.

- (3) Determine the VE corrected range for the nonregistering battery by algebraically adding the VE range correction to the GFT range of the registering battery.

- (4) Using the GFT setting for the registering battery, determine the elevation and fuze setting corresponding to the VE corrected range ((3) above).

- (5) Construct the GFT setting for the nonregistering battery by placing the hairline over the GFT range to the registration point for the registering battery and drawing the elevation gageline over the elevation determined in (4) above.

- (6) Draw the time gageline over the fuze setting obtained. This applies the registration total fuze correction to the fuze setting corresponding to the elevation determined in (4) above.

★*Example:* Battery B (155-mm howitzer M109) has registered and determined the following GFT setting: GFT B: Charge 5, lot YS (green bag), range 6820, elevation 368, time 23.8. The VE's for the base pieces are—

A: -0.9 m/s

B: -3.0 m/s

C: -5.0 m/s

The comparative VE's of the base pieces for A and C are—

A: +2.1 m/s (-0.9 - (-3.0))

C: -2.0 m/s (-5.0 - (-3.0))

The muzzle velocity unit corrections are—

A: -17.7 (Increase column)

C: +18.4 (Decrease column)

The VE range corrections are—

A: -40 meters (-17.7 × +2.1 = -37)

$$C: +40 \text{ meters } (+18.4 \times -2.0 = +37)$$

The VE corrected ranges for Batteries A and C then become the GFT range for Battery B plus the range correction.

$$A: 6780 (6820 - 40)$$

$$C: 6860 (6820 + 40)$$

Using the GFT setting for Battery B and the corrected ranges determined for Batteries A and C, read the elevation and fuze setting under the appropriate gagelines. The GFT settings are—

GFT A: Charge 5, lot YS, range 6820, elevation 365, time 23.6.

GFT C: Charge 5, lot YS, range 6820, elevation 371, time 24.0.

23-3. Calibration Corrections for Individual Pieces of a Battery

a. Calibration corrections to compensate for the variation in shooting strengths of the pieces of a battery are applied to the quadrant elevation. The individual piece correction is based on the variation of the shooting strength of each piece compared to that of the base piece.

b. In area fire, calibration corrections should be applied to any piece for which the VE varies by more than 1.5 meters per second from that of the base piece. Calibration corrections for various ranges may be computed and tabulated on a card which is furnished to the chief of section. The chief of section determines the appropriate correction and applies it to the announced quadrant elevation.

c. When special corrections are to be used to achieve a particular burst pattern, calibration

corrections are determined and applied to all pieces in the battery.

d. The procedure for determining the calibration correction for an individual piece(s) of a battery is as follows:

(1) Determine the comparative VE of the piece(s) with respect to the base piece by subtracting the calibration VE of the base piece from that of the piece(s) in question.

(2) Determine the muzzle velocity unit correction from the Ground Data table at the entry range (to the nearest 100 meters), using the Decrease (Increase) column if the sign of the comparative VE ((1) above) is minus (plus).

(3) Determine the calibration correction in meters by multiplying the comparative VE by the muzzle velocity unit correction.

(4) Determine the calibration correction in mils by dividing the calibration correction in meters by the *change in range for a 1-mil change in elevation (m/mil)*. The meters per mil is determined from the Ground Data table at the entry range to the nearest 100 meters.

Example: A 155-mm howitzer M109 battery has been assigned a final protective fire at a chart range of 7,130 meters. Calibration corrections are to be applied. The comparative VE's from a calibration with charge 5 green bag are as follows:

Piece number	Calibration VE	Piece number	Calibration VE
1	-2.1 m/s	4	-3.4 m/s
2	-2.7 m/s	5	-4.3 m/s
3 (base piece)	-3.0 m/s	6	-4.3 m/s

★Following the procedure described in above, compute the calibration corrections as follows:

Piece No.	Comparative VE		MV unit corrections		Cal corr (meters)		m/mil	Cal corr mils
1	+0.9	X	-18.2	=	-16	+	13	-1
2	+0.3	X	-18.2	=	-5	+	13	0
3	0	X	-----	=	-----	+	-----	0
4	-0.4	X	+19.0	=	+8	+	13	+1
5	-1.3	X	+19.0	=	+25	+	13	+2
6	-1.3	X	+19.0	=	+25	+	13	+2

e. If time fuze is to be used, a calibration fuze correction corresponding to the calibration correction for range (elevation) must be determined and applied. The following proportion may be used to determine the time correction.

$$\frac{\text{Calibration fuze correction}}{\text{difference in fuze setting for 100-meter range change}} = \frac{\text{Calibration correction in meters}}{100 \text{ meters}}$$

The difference in fuze setting for a 100-meter range change is determined by entering the Ground Data table with the elevation for the base piece. The difference between the fuze settings corresponding to the two listed elevations which bracket the base piece elevation is the

desired difference in fuze setting for a 100-meter range change. If the elevation for the base piece is listed in the firing table, the difference used is that between the fuze setting corresponding to the base piece elevation and that corresponding to the next higher (lower) listed elevation when the calibration correction in meters is plus (minus).

f. When a GFT with a current GFT setting is available, the corrections are determined as in d(3) above. The corrections are added algebraically to the GFT range. The hairline of the GFT is placed over the corrected range and the elevation and fuze setting are read under the appropriate gagelines. This procedure is repeated for each piece.

Section II. POSITION CORRECTIONS

23-4. General

a. Position corrections are corrections for individual pieces to compensate for the difference between the pattern formed by the pieces in the position area and the desired pattern of burst at the target. Position corrections may be required because of abnormal dispersion or concentration of the pieces or because of the location, size, or shape of the target.

b. Generally, position corrections are applied in area missions only if the depth of the position is abnormally great. A deflection difference is usually used in an area mission to correct for an abnormal width of battery.

c. In rare cases, such as positions in mountainous terrain, corrections may be needed for differences in the altitude of the pieces. The correction for vertical displacement will be negligible and is ignored unless the terrain is extremely rugged. The correction for the range effect is determined by using the GST to compute the amount of site necessary to correct for vertical displacement of the piece from the battery center. This change in site may be multiplied by the meters per mil from the tabular firing tables to obtain the equivalent range correction. The equivalent range correction may also be obtained from the GFT by applying the site as a change in elevation. The range

correction obtained is combined with other position corrections to give the total correction.

23-5. Preparation of M10 or M17 Plotting Board for Determining Position Corrections

When the M10 or M17 plotting board is used to determine position corrections, the piece locations and desired sheaf must be plotted to scale on the plotting board. Before the locations of the pieces are plotted, the centerline on the transparent disk (red 32 at top) must be aligned so that it coincides with the arrow on the gridded base of the board.

a. The piece locations contained in the battery executive officer's report, oral or sketch (fig. 23-1), are plotted on the transparent disk of the plotting board. Each small square of the base is assigned a value of 5 meters to facilitate measurement. Pieces are plotted with the center of the board representing the battery center; for example, a piece which is 30 meters right of, and 20 meters behind, the battery center would be plotted 6 squares right of, and 4 squares in rear of, the center of the board.

b. For weapons that are equipped with the 0-3200-mil panoramic telescope, an index for reading deflections is placed on the base opposite the referred deflection. For weapons that are equipped with the 0-6400-mil panoramic

telescope, the red arrow at the 0 index is used for reading deflections and the scale is renumbered as indicated in figure 23-2.

c. Lines representing the type of sheaf desired are drawn on the base (fig. 23-2). The lines are drawn parallel to the direction-of-fire arrow and to the same scale as that used for plotting the piece locations; they are spaced according to the type of sheaf desired ((1) through (3) below).

(1) *Open sheaf*—lines are parallel to direction of fire and equally spaced corresponding to the effective width of the burst.

(2) *Converged sheaf*—no lines are needed; the center of the board represents the convergence of the sheaf.

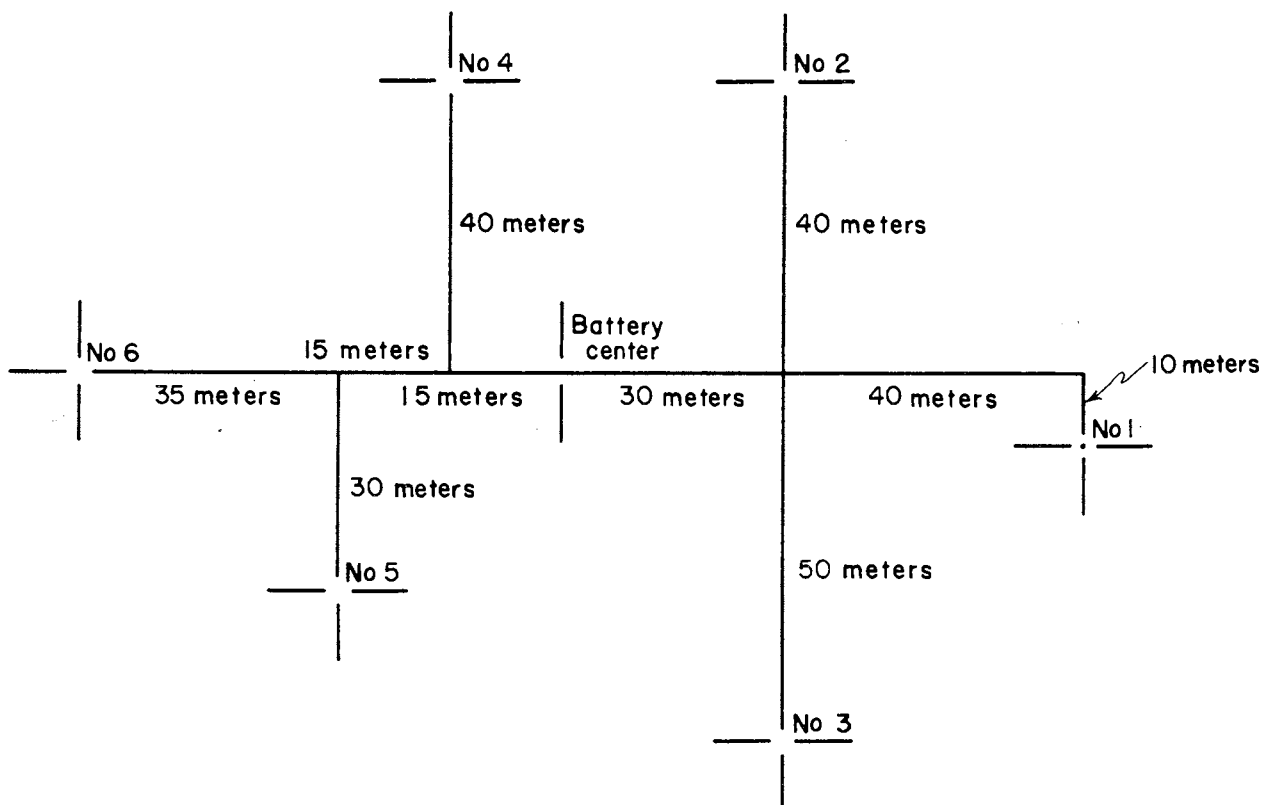
(3) *Special sheaf*—each desired point of burst would be plotted.

23-6. Computation and Application of Position Corrections

a. After the plotting board has been prepared, position corrections in meters for deflection and range for each piece of the battery may be graphically obtained for any desired direction of fire. The plotted positions correspond to the uncorrected burst positions as well as piece positions.

b. The direction of fire is set off on the plotting board by rotating the transparent disk until the desired deflection is opposite the index.

c. The deflection correction in meters for each piece (burst) corresponds to the distance and direction (right or left) between the plotted burst and its appropriate place in the constructed sheaf. Starting with the right burst, each burst is moved to the nearest sheaf line, with no more than one burst to a line. The



★Figure 23-1. Executive officer's sketch of an abnormal battery position.

bursts need not be placed in the sheaf in the numerical order of piece numbers. The correction in meters is converted to mils by dividing the shift in meters by the chart range in thousands to the nearest hundred meters (mil relation).

d. The range correction in meters for each piece (burst) corresponds to the distance and direction (over or short) between the plotted burst and the line at chart range (center of board) perpendicular to the direction of fire.

(1) Range correction in meters is converted to mils of elevation by dividing by the meters per mil of elevation factor.

(2) Range correction is converted to a time correction in the manner described in paragraph 23-3e.

e. The following example illustrates the procedure for computing and applying position corrections when the plotting board is used:

Example: A 155-mm howitzer M109 battery is laid, collimators have been emplaced, and deflection has been reset to 3200. The pieces are distributed as shown in figure 23-1. The final protective fire assigned to the battery is at a chart range of 5,710 meters. The chart deflection to the FPF is 2,850 mils. The long axis of the FPF is perpendicular to the direction of fire. Determine position corrections, using charge 5 fuze quick, open sheaf.

(1) Remove the disk from the plotting board and draw six lines parallel to the arrow 50 meters apart, with the two centerlines 25 meters right and left respectively of the arrow. (Scale is one small square = 5 meters.)

(2) Replace the disk and orient the 0-3200 line of the disk over the arrow with the red 32 on the disk at the head of the arrow.

(3) Plot the pieces on the disk.

(4) Rotate the disk until 2850 (red scale) is opposite the red arrow.

★(5) Determine the number of meter's correction for deflection to move each burst to the appropriate place in the sheaf.

Number 1, right 55 meters.

Number 2, right 10 meters.

Number 3, right 30 meters.

Number 4, left 47 meters.

Number 5, left 6 meters.

Number 6, left 64 meters.

★(6) Convert correction for deflection from meters to mils by dividing the correction in meters by the chart range in thousands to the nearest hundred meters.

Number 1, right 10 (55/5.7)

Number 2, right 2 (10/5.7)

Number 3, right 5 (30/5.7)

Number 4, left 8 (47/5.7)

Number 5, left 1 (6/5.7)

Number 6, left 11 (64/5.7)

★(7) Determine the range correction in meters required to bring each burst to the line at chart range perpendicular to the direction of fire.

Number 1, -14 meters.

Number 2, -48 meters.

Number 3, +37 meters.

Number 4, -33 meters.

Number 5, +38 meters.

Number 6, +22 meters.

★(8) Convert range correction in meters to mils of elevation by dividing by the meters per mil factor for the chart range to the nearest 100 meters.

Number 1, -1 mil (-14/16).

Number 2, -3 mils (-48/16).

Number 3, +2 mils (+37/16).

Number 4, -2 mils (-33/16).

Number 5, +2 mils (+38/16).

Number 6, +1 mil (+22/16).

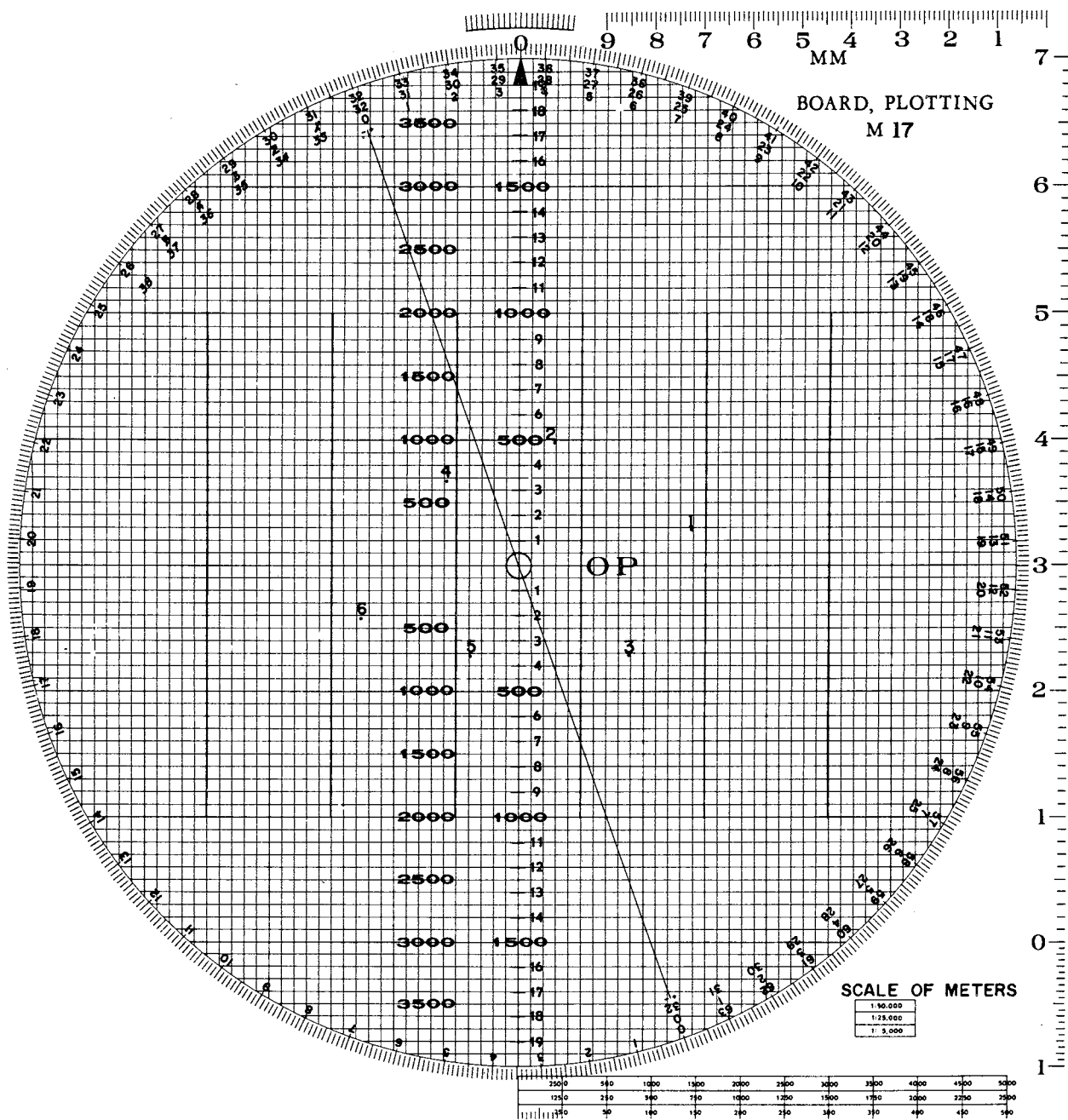
★f. Position corrections may also be applied by using the GFT in conjunction with the M17 plotting board. This solution should be employed whenever possible and especially when a valid GFT setting is being used.

(1) The deflection correction for each piece is determined as in c above.

(2) The individual elevations and times to be fired are obtained by applying the range corrections determined from the plotting board to the chart ranges. The hairline is placed over these corrected ranges and the corrected elevations and times are read under their respective gagelines.

Example: Battery and target information are as in the preceding example. In addition, the following GFT setting is in use: GFT B: Chg 5, Lot XY, Rg 6360, EL 344, TI 21.8.

a. Steps (1) through (5) of the preceding example would still be followed.



★Figure 23-2. Use of the M17 plotting board.

b. Convert the deflection corrections in meters to deflection corrections in mils.

#1 R10 (R55/5.7)	#4 L8 (L47/5.7)
#2 R2 (R10/5.7)	#5 L1 (L6/5.7)
#3 R5 (R30/5.7)	#6 L11 (L64/5.7)

c. Step (7) of the preceding example would still be followed.

d. Determine the corrected ranges by expressing the range correction to the appropriate accuracy and applying each to the chart range.

#1 -14 (-10)	#4 -33 (-30)
--------------	--------------

#2 -48 (-50)	#5 +38 (+40)
#3 +37 (+40)	#6 +22 (+20)

Note. Chart range is determined to the nearest 10 meters so each range correction is also expressed to this accuracy.

e. Elevations and times are determined as follows:

	<i>Elevation</i>	<i>Time</i>
#1	297	19.1
#2	295	18.9
#3	300	19.3
#4	296	19.0
#5	300	19.3
#6	299	19.2

Section III. SPECIAL CORRECTIONS

23-7. General

Special corrections are individual piece corrections applied to deflection, fuze setting, and quadrant elevation to place the burst in a precise pattern with the burst of each piece falling (theoretically) at a planned point on the target. In the rare cases when they are used, special corrections are normally computed at the battalion fire direction center. Special corrections are a combination of calibration corrections and position corrections.

23-8. Determination of Special Corrections

a. *Deflection.* The special corrections for deflection are solely position corrections and are determined as prescribed in paragraph 23-6c.

b. *Range (Elevation).* The special correction for range for each piece is the sum of its calibration correction in meters and position correction for range in meters. The total correction in meters is then converted to mils of elevation by dividing by the meters per mil factor determined at chart range.

c. *Time.* The special correction for fuze setting is determined by the following formula:

$$\frac{\text{Special fuze correction}}{\text{difference in fuze setting for a 100-meter change in range}} = \frac{\text{Special correction for range in meters}}{100 \text{ meters}}$$

The difference in fuze setting for a 100-meter change in range is determined at the elevation to the target before special corrections are applied by using the procedure described in paragraph 23-6f.

d. *Range (Correction).* When the GFT is used, the special correction for range in meters is applied to the chart range to determine the corrected range. The hairline of the GFT is placed over the corrected range for each piece and the elevation and time for each piece are read under the hairline or under the respective gage lines if established.

23-9. Application of Special Corrections

a. *Deflection.* The special correction for deflection is added to the chart deflection and deflection

CHAPTER 24

FDC PROCEDURES FOR SPECIAL SITUATIONS

Section I. GENERAL PROJECTILES

24-1. General

a. Chemical agents may be used to kill, injure, or harass personnel; to deny observation or use of an area, or to burn materiel. This section is concerned with the fire direction procedures used to employ chemical agents fired in chemical projectiles.

b. Paragraphs 13-1 through 13-5 contain a description of the uses of chemical projectiles and prescribe observer procedures for the adjustment of chemical projectiles.

24-2. Smoke Projectiles

a. *White Phosphorus*. Projectile WP is a bursting projectile which produces smoke, incendiary effect, and casualty effect. Against most targets, superquick fuze action is used. The action of the fuze and burster charge breaks the projectile and scatters the phosphorus particles above the ground. Since WP smoke rises, or pillars, it is not suited for maintaining a smokescreen; however, it is excellent for the initial buildup of a smokescreen.

b. *Smoke HC*. Projectile smoke HC is a base-ejection projectile and produces white smoke that is used primarily for screening. Smoke HC is always fired with time fuze and smoke HC is an effective screening agent but produces no casualty effect. Smoke HC readily absorbs and retains moisture, and it is more effective in rain or mist than it is in dry air.

c. *Colored Smoke*. Colored smoke is a base-ejection projectile and is normally used for prearranged signals or as an aid to the observer in identifying his rounds. Colored smoke is fired with time fuze. Except for the color of the smoke (red, green, or yellow), colored smoke is similar to HC smoke (white).

24-3. FDC Procedures for Adjustment of Projectile, WP

a. When fire for effect is to be fired with white phosphorus, the adjustment is conducted with HE, fuze quick.

b. WP projectiles are heavier than HE projectiles. When a change is made from HE to WP, a correction must be applied to compensate for the difference in the weight of the projectile. The correction is determined in the following manner:

- (1) Determine the difference in the weights (squares) of the projectiles by subtracting the weight of the HE used in the adjustment from the weight of the WP.
- (2) Determine, from the Ground Data table, the correction for an *increase* in projectile weight of one square at fire-for-effect chart range.
- (3) Determine the correction by multiplying the difference in the projectile weight ((1) above) by the unit correction ((2) above). The result is required to the nearest 10 meters.
- (4) Apply the correction to fire-for-effect chart range. Place the hairline of the GFT over the corrected range and read the elevation under the elevation gage-line.

Example: 155-mm howitzer M109 charge 5 green bag.

Fire-for-effect chart range-----	6,040 meters.
Weight of projectile HE-----	4 squares.
Weight of projectile WP-----	7 squares.
Difference in weight of projectiles	+3 squares.
Weight of projectile unit correction	+25 meters.
(range 6000).	
Range correction ((+25×3) =	+80 meters.
+75).	
Corrected range (6040+80)-----	6,120 meters.

Place the hairline over 6,120 meters and read the elevation under the elevation gage-line.

c. When necessary, the adjustment may be continued with one piece using WP until it is in the proper place. The correction for projectile weight is considered constant for a particular mission and need not be changed during the adjustment.

24-4. FDC Procedure for Adjustment of Base-Ejection Smoke

a. When base-ejection smoke is to be used, the adjustment is begun with one piece firing HE, fuze quick, and the lowest practical charge. The lowest practical charge is used to reduce the possibility of rupturing the canisters or scattering them on impact. An interior piece should be used in the adjustment. This will facilitate adjustment on additional points left or right of the initial adjusting point if they are needed.

b. When the observer has adjusted to within 100 meters of the adjusting point, he will usually request smoke and continue the adjustment until the smoke is at the proper location and height of burst. If more than one point is needed to screen an area, special corrections may be applied by using the M10 of M17 plotting board or the observer may adjust smoke onto each point. The procedure for firing base-ejection smoke is as follows:

- (1) Fuze time will be used. The fuze setting is determined by subtracting 2.0 from the fuze setting read under the time gage-line.
- (2) No height-of-burst correction (20/R) is applied when the adjustment with fuze time is begun. The height of burst is adjusted by increasing or decreasing site in accordance with the observer's corrections.

24-5. Building and Maintaining a Smoke-screen (Smoke HC)

a. Two rounds per point of impact should be fired as rapidly as possible to form an adequate smokescreen quickly. The smokescreen is then maintained by firing at the minimum rate necessary. The minimum rate of fire is governed largely by the velocity of the wind. A guide for the rate of fire for the 105-mm and 155-mm howitzers to maintain the screen is as follows:

Wind velocity (miles per hour)	Rate of fire per point of impact (number of seconds between rounds)	
	105-mm howitzer	155-mm howitzer
3-----	60	120
10-----	40	80
15-----	30	60

Note. The above rates must be modified according to what the observer sees on the ground.

b. The spacing of the points of fall which may be as great as 400 meters or as small as 30 meters, will depend on the speed and direction of the wind and the size of the front to be screened. The points of fall must be based on the observer's request and will be changed as necessary to correct for changes in weather and the tactical situation.

24-6. Toxic Chemical Projectile

a. When toxic chemical projectiles are used, particular attention must be given to selection of the area into which the chemical projectiles will be fired. Wind direction, velocity, and temperature gradient are factors of great importance in this selection and will determine the number of chemical projectiles to fire to achieve the desired results. If friendly troops are downwind from the target area, they must mask. See FM 3-10 for information concerning the computation of safety distance.

b. Toxic chemical agents are employed in either a vapor (nonpersistent) form or a liquid droplet (persistent) form. Each form requires a different fire direction technique to achieve the best results.

- (1) When a chemical projectile is used to produce a nonpersistent vapor hazard in the target area—
 - (a) A point-detonating fuze normally should be used.
 - (b) Surprise fire is essential. Sufficient artillery is required to insure that all rounds impact within 30 seconds.
 - (c) Distribution of fire is accomplished by assigning a separate point of impact to each battery-size unit.
- (2) When a chemical shell is used to contaminate the target area with persistent liquid droplets—
 - (a) A low airburst normally should be used.
 - (b) Surprise fire is not essential.
 - (c) Distribution of fire is accomplished by firing each group of rounds at a different point of impact. Normally, zone fire will give the best coverage.

c. When firing data are being computed for transfer of fire, a correction must be applied to the HE GFT setting to compensate for the increased weight of the toxic chemical projectile and an additional correction must be applied for a 1½ per-

cent increase in air density. The correction is determined as shown in the example below.

Example: 155-mm howitzer M109, charge 5, green bag.

Fire-for-effect chart range	6,040 meters
Weight of projectile HE	4 squares
Weight of projectile GB	7 squares
Difference in weight of projectiles	+ 3 squares
Weight of projectile unit correction (range 6000)	+ 25 meters

Range correction (25 x 3)	+ 75 meters
Air density correction for 1 percent (range 6000)	+ 10.0 meters
Range correction (10.0 x 1½)	+ 15.0 meters
Corrected range (6040 + 90)	6,130 meters

Place the hairline over 6,130 meters and read the elevation under the elevation gageline.

Section II. ILLUMINATING PROJECTILES

★ 24-7. General

a. Illuminating projectiles are provided for the 105-mm and 155-mm howitzers. The uses and procedures for the adjustment of these projectiles are covered in paragraphs 13-6 and 13-7.

b. This section will be devoted primarily to the FDC procedures applicable to the 155-mm howitzer when firing illuminating projectile M485 and fuze M565. FDC procedures for the 105-mm howitzer are the same except where indicated otherwise in this discussion.

24-8. Selection of Charge

When an illuminating projectile is to be fired, the lowest possible charge should be selected in order to reduce the possibility of ripping the parachute when the flare is ejected from the projectile.

24-9. Chart Data

a. The HCO plots the location and announces chart data as in any other mission.

b. The VCO determines and announces the vertical interval between the battery and the ground level in the area to be illuminated.

24-10. Firing Data

In converting chart data to firing data, the computer must consider the type of adjustment.

a. *Deflection.* Deflection corrections determined by firing HE are disregarded. The deflection to be fired depends on the type of adjustment.

(1) *One-gun.* The chart deflection is fired.

(2) *Two guns.* The chart deflection is fired by both guns.

(3) *Two guns, range spread.* The chart deflection is fired by both guns.

★(4) *Two guns, lateral spread.* The deflection for the right piece is the chart deflection minus 5 times 100/R. The deflection for the left piece is chart deflection plus 5 times 100/R.

★(5) *Four guns.* The two interior pieces fire the chart deflection. The deflection for the right piece is chart deflection minus 5 times 100/R. The deflection for the left piece is chart deflection plus 5 times 100/R.

b. *Elevation and Fuze Setting.* Range corrections determined from firing HE are disregarded. The range at which elevation and fuze setting for each piece are determined depends on the type of adjustment.

(1) *One gun.* The chart range is fired.

(2) *Two guns.* The chart range is fired.

(3) *Two guns, lateral spread.* The chart range is fired.

★(4) *Two guns, range spread.* One piece is fired at the chart range plus 500 meters and one piece is fired at the chart range minus 500 meters.

★(5) *Four guns.* The flank pieces are fired at the chart range; one interior piece is fired at the chart range plus 500 meters; the other piece is fired at the chart range minus 500 meters.

★*Note.* When firing illuminating projectiles other than M485, the lateral spread is plus and minus 4 times 100/R and the range spread is plus and minus 400 meters.

★24-11. Illuminating Graphical Firing Table

a. *General.* Graphical firing tables have been developed for use with illuminating projectiles M118 and M485 (155-mm) and M314 and

M314A2E1 (105-mm). Since the description of the scales and the determination of firing data as outlined in paragraphs 24-12 and 24-13 are basically the same for all models of illuminating graphical firing tables, this section is limited to a discussion of the M485 illuminating projectile and firing tables applicable to this projectile.

b. Description of the Graphical Firing Tables. The graphical firing table for the M485 is designated Scale, Graphical Firing, 155AH2ILLM485. A complete set of GFT's consist of two rules. Each rule consists of a cursor and a base which is 18 inches long and 3½ inches wide. A set of scales for a single charge is inscribed on each side of a base. Charges 1 and 3 are on rule 1. Charges 5 and 7 are on rule 2. There is sufficient overlay between these four charges to permit the elimination of charges 2, 4, and 6. Charge 1 data start at a range of 500 meters, making it possible to provide illumination of the firing position and the area immediately in front of it. Fuze activation and parachute deployment at the shorter ranges of charge 1 occur on the ascending leg of the trajectory. The scales on the GFT, from top to bottom, are as follows:

(1) *100/R scale.* The 100/R scale denotes the number of mils necessary to shift the burst 100 meters laterally for a given range.

(2) *Range scale.* The range scale is the basic scale on the GFT and all other scales are plotted with reference to it. Range is read to the nearest 10 meters.

(3) *Elevation-to-impact scale.* The elevation-to-impact scale is graduated in mils. Low-angle elevations increase from left to right and are read to the nearest mil. For charge 1 only, high-angle elevations to impact are printed on the right side of the scale. The high-angle elevations increase from right to left and are printed in red. The elevation-to-impact scale is used to determine the range (on the range scale) to which a nonfunctioning projectile (dud) will travel.

(4) *Height-of-burst scales.* At the left and right of the main body of each set of scales are the height-of-burst scales. The scales are graduated in 50-meter increments and extend from 350 meters to 950 meters, except the scales for charge

1, which extend from 350 meters to 900 meters. Charge 1 stops at 900 meters because at the lowest range the QE required to reach 950 meters exceeds the capability of the weapon.

(5) *Quadrant elevation scale.* Corresponding to each listed height of burst is the QE necessary to achieve that height of burst and the desired range. The QE scale is graduated in mils and is read to the nearest mil. QE's for charge 1 are for both low and high angle fire, depending on the range and the height of burst desired. QE's for charges 3, 5, and 7 are for low angle fire only.

(6) *Fuze setting scale.* The fuze setting (FS) scale consists of red lines for each full fuze setting for the M565 fuze. The value of each line is printed in red at the bottom of the scale. Fuze setting is read for the desired range and height of burst to 0.1 accuracy by interpolation.

★ 24-12. Determination of Data With the Illuminating Graphical Firing Table

a. Quadrant elevation and fuze setting for a given range and charge are determined by placing the hairline over the range to the point to be illuminated. The quadrant elevation scale to use is determined by adding algebraically the optimum height of burst to the battery-target vertical interval and rounding the sum to the nearest 50 meters. The quadrant elevation is read at the intersection of the hairline and the selected quadrant elevation scale. The fuze setting to fire is obtained by interpolating between the red fuze setting arcs for the point of intersection of the hairline and the selected quadrant elevation.

b. A heavy black arrow on the quadrant elevation scale indicates the part of the trajectory which is at or near the summit and which does not exceed by 50 meters the height of burst which it represents.

c. The major improvements in the M485 projectile over other illuminating projectiles are greater illumination, longer burning time, slower rate of descent, and the use of a drogue chute which reduces chute failures but which requires fuze activation prior to main chute deployment. Whereas the optimum height of burst for all other illuminating projectiles is 750 meters, the M485,

because of the longer burning time and slower rate of descent, should be burst at a height of 600 meters above the area to be illuminated.

d. The M485 is ballistically similar to the M107 HE projectile. If a current HE GFT setting is available, greater initial accuracy can be achieved with the M485 by constructing this GFT setting on the illuminating GFT. This is possible because the range scales are constructed logarithmically rather than linearly. The GFT setting geometrically applies a constant range K instead of the variable range K possible with slant scale GFT's; however, the error is negligible, considering the size of the area of illumination.

e. The HE GFT setting is placed on the illuminating GFT by placing the hairline of the cursor over the adjusted elevation on the elevation-to-impact scale and drawing a gageline on the range scale over the GFT setting range. Mark this gageline RG. Data may now be determined by placing the range gageline over the range to the point to be illuminated, on the range scale, and reading the quadrant elevation and fuze setting at the intersection of the selected quadrant elevation scale and the hairline.

f. The following example illustrates the construction of the GFT setting and the determination of quadrant elevation and fuze setting:

(1) *Given:*

(a) GFT B: Chg 5, lot XY, rg 5840, el 302.

(b) Chart range to the point to be illuminated: 7,260 meters.

(c) Vertical interval: +60 meters.

(2) *Required:* Construct the GFT setting and determine the quadrant elevation and fuze setting to fire.

(3) *Solution:*

(a) Place the hairline of the cursor over the adjusted elevation (302) on the elevation-to-impact scale.

(b) Draw a range gageline on the range scale over the GFT setting range (5,840 meters) and mark it RG.

(c) Place the range gageline over the chart range to the point to be illuminated.

(d) Determine the quadrant elevation scale to use.

1. Optimum HOB: 600 meters.

2. Vertical interval: +50 meters (nearest 50-meter increment).

3. Quadrant elevation scale to use: 650 (600 + (+50)).

(e) Read, at the intersection of the hairline and the 650-meter quadrant elevation scale, the quadrant elevation to fire: QE 547.

(f) Interpolate between the red fuze setting arcs bracketing the point of intersection of the hairline and the 650-meter quadrant elevation scale to obtain the fuze setting to fire: 26.6.

g. The procedure for determining the quadrant elevation and fuze setting for the ascending branch is the same as the procedure for the descending branch.

24-13. Determination of Firing Data Based on Subsequent Observer Height-of-Burst Corrections

Data based on subsequent height-of-burst corrections are determined in the following manner:

a. Determine the quadrant elevation scale to use.

(1) Observer corrections to height-of-burst are always given in multiples of 50 meters.

(2) Observer corrections are added algebraically to the height of burst previously used to obtain the height of burst for the next round (s).

b. Using the appropriate quadrant elevation scale, determine the quadrant elevation and fuze setting as outlined in paragraph 24-12.

24-14. Determination of Firing Data With the Tabular Firing Tables

★ a. *Elevation and Fuze Setting.* For each 100 meters in range, part 3 of the firing tables shows the elevation and fuze setting for the optimum height of burst (600 meters above the pieces) and the change in elevation and fuze setting for a 50-meter change in height of burst. (Chart range is rounded to the nearest 100 meters in all cases.)

b. *Height-of-Burst Correction.* The observer may make height-of-burst corrections in increments of 50 meters during adjustment. To determine the total height-of-burst correction, the computer adds the observer's cumulative height-of-burst correction and the vertical interval (para 24-9b) rounded to the nearest 50 meters. The corrections to elevation and fuze setting are determined as follows:

(1) Divide the total height-of-burst correction by 50. This gives the number of 50-meter increments.

(2) Determine from the firing tables the values listed as change in elevation and fuze setting for a 50-meter change in height of burst corresponding to the new chart range.

(3) Multiply the number of 50-meter increments from (1) above by the values from (2) above.

c. Fuze Setting and Quadrant Elevation. The fuze setting to be fired is the sum of the fuze setting (*a* above) and the fuze setting correction for height of burst (*b* above). The quadrant elevation to be fired is the sum of the elevation (*a* above) and the elevation correction for height of burst.

24-15. Corrections

The proper height of burst, time of burning, and distance between bursts of adjacent rounds may vary from one projectile lot to another because of variations in the illuminant. Storage conditions and length of storage may cause a variation in performance of the illuminant. Large variations from the optimum height of burst can be expected. To prevent waste of ammunition, the FDC personnel must record the corrections from all adjustments and determine the best height of burst for each ammunition lot. A correction to obtain the best height of burst should be applied at the start of the adjustment.

Section III. PROPAGANDA PROJECTILE

24-16. General

a. Artillery may be used to deliver psychological warfare leaflets. Pinpoint accuracy is not required for propaganda missions. Twenty-five rounds from a 105-mm howitzer normally will cover an area 500 by 500 meters. Corps artillery or higher headquarters normally will issue the order to fire propaganda projectile and will specify the area to be covered and the amount of ammunition to be expended.

b. There is no standard propaganda projectile. Ordnance will prepare and issue the ammunition. Usually, an HC smoke projectile with the filler and booster replaced by leaflets, is used. Ordnance must weight and mark the weight on the projectile.

24-17. FDC Procedure for Firing Propaganda Projectile

The data for firing propaganda are determined in the same manner as that for an HE mission with the following exceptions:

a. The height of burst above ground is initially 100 meters. Wind velocity and direction may affect the leaflets in such a way that a lower height of burst may be requested by the observer.

b. A correction for the large variation in weight from that of a standard weight projectile must be determined and applied to chart range. Elevation and fuze setting are determined at the corrected range by using the HEGFT setting, if any.

Section IV. ASSAULT FIRE

24-18. General

Assault fire is a special technique of indirect fire. The FDC personnel, as part of the assault fire team, should make certain preparations prior to the occupation of position. Firing charts should be plotted, initial firings data should be computed, and deflection shift and quadrant change cards

should be prepared. The planning and preparations should provide excellent initial data, resulting in a short adjustment phase. Assault fire is most effective against a target with a significant vertical dimension, since advantage may be taken of the small vertical probable error of the weapon.

24-19. FDC Procedure for Assault Fire

a. An FDC for each emplaced weapon is employed to obtain the necessary accuracy. Normal observed fire and FDC procedures are used during the adjustment. The maximum charge which will clear the intervening crests is used to effect maximum muzzle velocity and penetration. The tabular firing tables must be used, because the minimum range of GFT's for the higher charges precludes the use of GFT's.

b. Observer procedures for assault fire are described in paragraphs 13-9 through 13-14.

c. After the chart data are determined for the first round in fire for effect, the use of the firing chart is discontinued. During the remainder of the mission, a two-man team, consisting of a deflection computer and a quadrant computer, determines the data to place the burst directly on the target.

(1) Before the start of the mission, the deflection computer prepares a deflection shift card

(fig. 24-1) for the chart range to the target as an aid in computing required deflection changes. The card is prepared by using the C and D scales and M gagepoint of any GST. The range to the target is set on the C scale opposite the observer's correction on the D scale, and the deflection shift in mils is read opposite the M gagepoint. The deflection shift in mils is rounded to the nearest whole mil for observer corrections greater than 2 meters and to the nearest one-fourth mil for observer corrections of 2 meters or less.

(2) Deflections can be set off to one-fourth mil on weapons equipped with the M100-series sights. The use of a deflection board is required for other sights. A deflection board (fig. 4-15) is used to set off $\frac{1}{4}$ -mil units of deflection. To determine a new deflection to include the observer's corrections, the computer applies the required deflection shift to the previous deflection by use of the LARS rule (left, add; right, subtract).

Example: Chart range 1,500 meters.

Quadrant change card	Chart range 1,500 meters
Observer's site Correction (in meters)	Quadrant change (in mils)
1/2	0.3
1	0.7
2	1.4
3	2
4	3
5	3
6	4
7	5
8	5
9	6
10	7

★Figure 24-1. Deflection shift card.

★Previous Deflection fired	Observer's Correction (meters)	Deflection Shift from Card (Mils)	New Deflection Command
3210	Right 7	Right 5	3205
3205	Left 4	Left 3	3208
3208	Left 2	Left 1 1/4	3209 1/4
3209 1/4	Right 1	Right 3/4	3208 1/2
3208 1/2	Left 1/2	Left 1/4	3208 3/4

(3) The quadrant computer prepares in advance a quadrant change card (fig. 24-2) for the chart range to the target as an aid in computing the required quadrant change (to the nearest one-tenth mil (see (2) above)). The quadrant card is prepared in the same manner as the deflection shift card. The quadrant change in mils is rounded to the nearest whole

mil for observer corrections greater than 2 meters and to the nearest one-tenth mil for observer corrections of 2 meters or less. The gunner's quadrant is used throughout the mission. To determine a new quadrant to include the observer's correction, the computer applies the required quadrant change in the appropriate direction to the previous quadrant fired.

Example: Chart range 1,500 meters.

Previous QE fired	Observer's corrections (meters)	QE change from card (mils)	New QE command
30.0	UP 4	+3	33.0
33.0	DOWN 2	-1.4	31.6
31.6	UP 1/2	+0.3	31.9

Section V. DESTRUCTION MISSIONS

24-20. General

a. A destruction mission is a mission to destroy a target by one or more direct hits. There are two primary considerations in the selection of the weapon-charge combination to be used;

a large enough projectile to accomplish the mission should be selected, and the weapon-charge combination should give the smallest PE_r possible. Most destruction missions should be fired by medium or heavy artillery; however, in

<u>Deflection shift card</u>	<u>Chart range 1,500 meters</u>
Observer's deflection Correction (in meters)	Deflection shift (in mils)
1/2	1/4
1	3/4
2	1 1/4
3	2
4	3
5	3
6	4
7	5
8	5
9	6
10	7

★Figure 24-2. Quadrant change card.

some situations light artillery can be effective. The 8-inch howitzer is an excellent weapon for a destruction mission because of its small probable error and the effectiveness of its projectile.

b. A destruction mission is a precision mission. Because the destruction of the target is the objective, the observer, not the S3, will terminate the mission as soon as destruction has been accomplished.

24-21. FDC Procedure for Destruction Missions

a. The correct deflection for a destruction mission is determined in the same manner as in a precision registration.

b. An adjusted quadrant elevation is determined after six definite FDC range spottings in fire for effect. The adjusted QE is computed and used to the nearest 0.1 mil. Firing is con-

tinued, if necessary, with the adjusted QE (nearest 0.1 mil). A new adjusted QE is computed after each succeeding group of six definite FDC range spottings. If a second adjusted QE is computed, one-half of the computed elevation change is applied to the previous adjusted quadrant elevation. If a third adjusted QE is required, one-third of the computed elevation change is applied. If a fourth or any succeeding adjusted QE's are required, one-fourth of the computed elevation change is applied.

c. When a projectile-fuze combination other than HE-quick is desired, the change is made after the first adjusted QE is computed. If the desired combination has different ballistic properties, appropriate corrections for the nearest listed chart range must be applied.

Example: 155-mm howitzer M109, charge 5 green bag, shell HE, fuze quick, range 5040.

First adj QE=244.5 mils.

S3 directs fuze concrete piercing.

FT 155-AH-2 data:

Correction for fz CP (1% increase air density)
= +7.4 meters.

C=5.8 mils.

Correction to be applied:

$$\frac{+7.4}{100} \times 5.8 = +0.43$$

Increase in QE=0.4 mil.

Section VI. FINAL PROTECTIVE FIRES

24-22. General

A final protective fire (FPF) is an immediately available prearranged barrier of fire designed to impede enemy movement across defensive lines or areas. The normal ground use of an FPF is to establish prearranged close-in defensive fires which include coordinated employment of other artillery fires, minefields, obstacles, final protective machinegun fires, and mortar final protective fires. Each battery is assigned one final protective fire. The battery normally is laid on the FPF when it is not firing other missions. The FPF may be fired on prearranged signal or on call from the supported unit. The firing of an FPF may be repeated on call as often as necessary. When possible, the data for the FPF should be verified or corrected by the firing of check rounds.

24-23. Characteristics of Final Protective Fires

The firing of a battery final protective fire, either individually or coordinated with other batteries, is based on the following:

a. Width of Final Protective Fire. The width (or the length) of the FPF (fig. 24-3) which can

be covered by a single battery without shifting its fire should not exceed the width of an open sheaf as shown in table 2-1. If the width (length) of the area to be covered exceeds the width of an open sheaf as shown in table 2-1, greater protection is obtained if sufficient reinforcing artillery is assigned to allow each battery to limit its fire to the width of an open sheaf. Assigning a battery a final protective fire beyond its capability to cover without shifting fires greatly reduces the effectiveness of this FPF as a "barrier of fire."

b. Preparation of Data. The final protective fire may be at any angle to the direction of fire. Special corrections normally are used to place each burst in the proper position. Map data for an FPF are taken from the center point of the FPF line. The angle between the FPF and the direction of fire is used to secure a plot of the FPF on the device (M10 plotting board) that is used to compute individual corrections for each piece. Firing data are determined by using normal procedures except for—

- (1) *Distribution.* A final protective fire is fired with special corrections.
- (2) *Method of fire.* Fire is continuous fire at maximum rate.

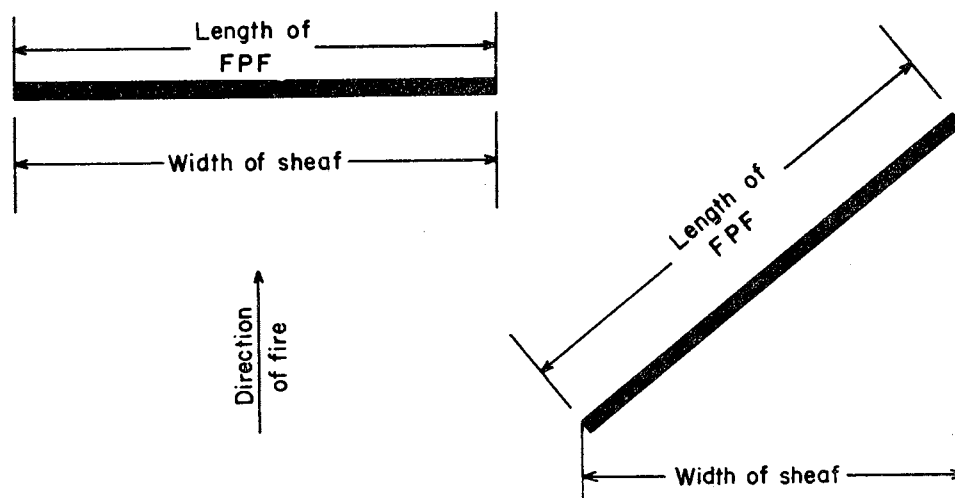


Figure 24-3. Final protective fire

Section VII. COMBINED ADJUSTMENT

24-24. General

a. Observer procedure for combined adjustments is described in paragraphs 13-15 through 13-20.

b. Targets or adjusting points may be designated by one observer or the S3. When direct communication between observers is impossible, the FDC must coordinate the operations for the observers.

c. Only one piece is used in adjustment.

24-25. FDC Procedure for Combined Adjustments, Observation Posts Plotted

a. For combined adjustments, the target is plotted and firing data are determined in the normal manner. Orientation data for the OP's may be determined in the manner prescribed in paragraph 19-29.

b. After the initial round is fired and the ob-

servers have reported the directions (or deviations), rays are drawn from each OP at the reported directions. The intersection of the rays is the location of the burst. A range and deflection correction to place the burst at the target is measured. New firing data are computed and fired.

Example: 155-mm howitzers M109, charge 5 green bag.

Chart range to target.....	5,900 meters.
Chart deflection.....	3,427 mils.
QE fired (el (289) + site (+6)).....	295 mils.
Fired deflection (df corr 0).....	3,427 mils.
Measured range to burst location.....	5,790 meters.
Correction for range (5900-5790) ..	+ 110 meters.
Corrected range (5900+110).....	6,010 meters.
Elevation corresponding to 6,010 meters.	297 mils.
New QE (297 + (+6)).....	303 mils.
Measured deflection to burst location.	3,433 mils.
Deflection correction (3427-3433) ..	R6 mils.
New deflection (3427 + R6).....	3,421 mils.

Section VIII. SOUND, FLASH, AND RADAR MISSIONS

24-26. Target Acquisition Elements

a. *Target Acquisition Battalion.* The target acquisition battalion assigned to corp artillery has the means for locating targets, adjusting and registering friendly artillery fire, and providing assistance in the calibration of artillery. The target acquisition batteries of the battalion contain sound, flash, and radar platoons which are deployed to cover common areas in support of the corps artillery mission.

b. *Target Acquisition Platoon.* The target acquisition platoon organic to direct support battalions has the means for locating targets and adjusting and registering friendly artillery and mortars.

c. *Target Acquisition Techniques.* The techniques employed by sound, flash, and radar units are covered in FM 6-122, FM 6-160, and FM 6-161.

24-27. Capabilities and Limitations

The capabilities of sound, flash, and radar complement one another.

a. *Sound.* Sound locations and adjustments are not affected by poor visibility; however, high winds interfere with the operation of sound ranging equipment. Sound ranging is employed to

locate hostile artillery and to adjust friendly artillery.

b. *Flash.* Flash ranging is the most accurate means of locating targets; however, the efficiency of the flash ranging observation posts may at times be limited by poor visibility and adverse terrain. The flash ranging platoon is used to—

- (1) Locate hostile artillery and other hostile targets in the area.
- (2) Adjust and register friendly artillery.
- (3) Assist in the performance of comparative calibration of cannon artillery by providing the mean burst location.

c. *Radar.* Counterbattery radars are organic to the target acquisition batteries within the field artillery target acquisition battalion (FATAB). Countermortar radars are organic to the target acquisition elements of direct support artillery battalions. Radar operations are not affected by poor visibility due to darkness or fog; however, heavy rain or snow can reduce its capability. Mountainous terrain somewhat reduces mobility of the radar; however, due to the high angle of fire, the radar can be very effective. Counterbattery and countermortar radars are used to locate hostile artillery and mortars and to register and adjust

friendly artillery and mortars. The counter-mortar radar also has the capability of providing survey information when normal survey means are not available. The counterbattery radar set, AN/MPQ-10A, currently authorized within the FATAB TOE, is limited in its ability to locate hostile artillery firing low trajectory because of inherent countermortar design features.

24-28. Target Designation

a. Target location reports normally will include the coordinates (grid or polar), altitude of the target, the times the target was active, accuracy of the location, and description of the target. In the absence of survey control, target acquisition elements can report targets in relation to a reference point, previous targets, or a registration point which has been located relative to both the firing unit and the locating agency. Sound and radar units must determine the altitude of targets from maps; however, flash platoons can always determine relative altitudes.

b. The location of a target or registration point can be given to a target acquisition agency as either grid coordinates or a shift from a known point.

24-29. Adjustment of Fire

a. The accuracy of the location, the type of target, and the time available determine whether targets located by sound, flash, or radar may be attacked with or without adjustment.

b. When targets are to be attacked without adjustment, FDC procedures are the same as those used for any fire-for-effect mission. Sound ranging platoons may request one round to be fired after the fire for effect to plot the location of the effect, because many rounds bursting at one time make sound tapes difficult to read.

c. When sound, flash, or radar is used to conduct the adjustment of fire on a target, the FDC will receive a standard call for fire and subsequent corrections. The procedures are the same as those used in normal adjustment by an observer except that—

(1) Time of flight is given to the adjusting agency (e.g., sound platoon) prior to commencing fire. The commands SHOT and SPLASH are always given for each round.

(2) All adjustments are conducted with one weapon.

(3) Adjustments may contain refined corrections which would not be encountered in an observer adjustment (e.g., RIGHT 110, ADD 550), because the burst is located accurately.

(4) Sound-on-sound adjustments must be conducted with fuze quick.

(5) Counterbattery radar personnel may request the location of a point along the trajectory fired by the adjusting piece to assist in picking up the round. Normally, the location of the point will be given in terms of the firing azimuth and the altitude of the round at a distance of 1,000 meters from the weapon.

(6) High-angle fire must be used when counter-mortar radar is the adjusting agency.

(7) Normally, less ammunition will be used in an adjustment by sound, flash, or radar, but the adjustment may be slower than conventional means since each round must be plotted before determining corrections.

24-30. Conduct of Registrations

a. Artillery can be registered by means of sound ranging, flash ranging, and radar. However, sound ranging can be used only for an MPI registration, and since sound ranging is the least accurate and the most limited of these three, it should be used only when other means are not available.

b. The coordinates and altitudes of the registration point (point selected for HB or MPI) should be determined by the firing battalion in coordination with the target acquisition element. If the registration is to be a high burst or mean point of impact, the number of rounds fired is determined at the FDC; however, the target acquisition element may request one or more rounds fired AT MY COMMAND in order to orient the observers. These rounds may be requested to assure positive identification in the case of sound ranging or radar. A specified interval between rounds may also be requested. The target acquisition element determines the location of each round fired and reports this location after each round. This enables the FDC to determine the validity of each round. The sound and flash elements report the location of each round by grid coordinates, whereas the radar element reports the location either by grid coordinates or by polar coordinates.

★ Section IX. GUNNERY PROCEDURES FOR IMPROVED CONVENTIONAL MUNITIONS

★ 24-31. General

Gunnery procedures for the delivery of Improved Conventional Munitions (ICM) can be broken down into three areas — Firing Battery, Observer, and Fire Direction Center. Basic gunnery procedures learned for standard HE ammunition also apply to ICM; however, there are some variations with which personnel must become familiar.

a. Firing Battery.

(1) A major consideration of ICM is identification. The projectile is painted olive drab, is marked with the model number, and has a band of yellow diamonds around the ogive. In some instances the 105-mm projectile may not have this band of diamonds, but will have the band on the container and the ammunition box. Strict segregation must be maintained because these markings may become obscured by dirt.

(2) Normal storage, handling, and emergency destruction procedures also apply to ICM.

(3) ICM cannot be fired in direct fire as that term is presently defined. However, direct fire tables are included in the addenda to certain firing tables and are used by the chief of section for close-in battery defensive fires. These tables contain the quadrant and fuze setting for estimated ranges between 300 and 3000 meters. Wind direction and speed must be considered when firing close-in battery defensive fires in order to preclude danger to friendly troops. Also included are tables designed to provide rapid response indirect fire that can be used for close-in battery defensive fires. For actual direct fire in battery defensive fires, the Beehive round is still preferred.

b. Observed Fire.

(1) In order to aid the FDC, the observer must include an estimation of wind direction and speed in the call for fire. An accuracy of 100 mils in direction and 5 knots in velocity is desirable. A smoke or WP round may aid the observer in making his estimation.

(2) ICM is most effective against soft targets, such as troops in the open. The observer must be familiar with a comparison of effects between HE and ICM and the effects of terrain on the

effectiveness of ICM and must be capable of advising supported commanders on these effects.

(3) Some malfunctions (duds) do occur with ICM, particularly from a low air burst. The observer must report all duds and erratic rounds. Duds should be treated as potential mines or boobytraps.

(4) Surprise fire is most effective and desirable with ICM. When current corrections are not available, the observer should adjust with HE on a point near the target and then shift and fire for effect with ICM on the target.

(5) Procedures for adjustment of ICM are similar to HE adjustment. Range and deviation are corrected from the center of the effects pattern. Height of burst is corrected in 50-meter increments. How far UP or DOWN the observer should go depends on the experience gained with adjustment of this round. The basic criterion is that if a large number of duds are observed or the effects pattern appears too small, the observer should give an UP correction. This correction should not exceed 100 meters until the observer becomes familiar with the effects of changes in height of burst. The height of burst being too high does not appear to be critical and can be compensated for by changes in range and deviation.

(6) When adjusting close-in fires with ICM, the observer must start the adjustment at least 600 meters from friendly troops, depending on the relative positioning of the weapons, target, and friendly troops and on the wind direction and speed. The adjustment should be made with the entire battery and corrections made from the near edge of the effects pattern.

c. Fire Direction Center.

(1) The procedure for computing data for firing ICM is applicable under the following conditions:

(a) *Observer adjustment.* The adjustment may be conducted with either HE or ICM. Adjustment with ICM is not recommended since it eliminates the element of surprise.

(b) *Met plus VE.* Current met corrections must be available.

(c) *K-transfer*. Current registration corrections must be available.

(2) FDC procedures for ICM involve the use of appropriate firing table addenda to determine low level wind corrections and ballistic corrections to give the proper trajectory for ICM.

★ 24-32. Not Used

★ 24-33. Example Problem

The following example illustrates the procedures for firing ICM. Although the M449A1 projectile and M109 howitzer are used in the example, these procedures are applicable for all weapons when firing ICM.

a. Known Conditions.

Battery coordinates	3971016255
Battery altitude	432 meters
Target coordinates	3873023200
Target altitude	451 meters
Battery laying:	
Azimuth	350 mils
Referred deflection	3200 mils
GFT setting:	
GFT A: Chg 5, Lot YZ, rg 6480, el 344, ti 22.4	
Total deflection correction	R10
Line 01 of a current met message	013418 947115

b. Determination of QE to Target for HE Projectile.

Chart range	7030 meters
Site	+3 mils
Elevation	386 mils
QE	389 mils

c. Correction for Low Level Wind.

(1) Determine wind direction and speed from line 01 of the met message or from the observer's estimate.

Wind direction	3400 mils
Wind speed	18 knots

(2) Enter column 1, table A, FT 155-ADD-B-1, charge 5G, with the HE QE to the nearest listed value (390) and determine the low level wind correction factor from column 5.

Low-level wind correction factor	3.3 m/knot
----------------------------------	------------

(3) To determine the target displacement for low-level wind, multiply the wind speed by the low level wind correction factor and express the result to the nearest 10 meters.

Target displacement ($18 \times 3.3 = 59.4$) 60 meters

d. *Target Displacement*. Place the center of the target grid over the target and set off the met wind direction (3400) opposite the north index. This places the arrow pointing into the wind. Displace the target plot toward the arrowhead (into the wind) by 60 meters. Chart data to the wind displaced plot is measured as follows:

Range	6,970 meters
Deflection	3,696 mils

e. *Determination of QE and Fuze Setting*. Using the GFT and the GFT setting determine the QE and fuze setting to the wind displaced plot for projectile HE, M107.

Elevation	381 mils
Site	+3 mils
QE	384 mils
Fuze setting	24.6

f. Firing Data for Projectile M449A1.

(1) Apply the total deflection correction to the target to the chart deflection to determine the deflection to fire.

Total deflection correction for elevation	$381 = R9$
Deflection to fire	$3696 + R9 = 3687$

(2) Enter column 1, table A, at the value nearest the adjusted QE (385) to obtain the correction to QE from column 2. Express the correction to the nearest mil and add it algebraically to the adjusted QE.

Adjusted QE	384
Correction to QE	+27
QE to fire	411

(3) Enter column 1, table B, with the adjusted fuze setting (24.6) to obtain the correction to fuze setting from column 2. Algebraically add the correction to fuze setting to the adjusted fuze setting to obtain the fuze setting to fire.

Adjusted fuze setting	24.6
Correction to fuze setting	-1.1
Fuze setting to fire	23.5

(4) Data to fire are as follows:

Deflection	3687
Time	23.5
Quadrant	411

★ 24-34. Additional Information

Additional information concerning Improved Conventional Munitions is contained in FM 6-141-2.

Section X. DEAD SPACE

24-35. General

Dead space is the area within the maximum range of a weapon which cannot be covered by fire from a particular position because of intervening obstacles, the nature of the ground, characteristics of the trajectory, or the mechanical limitation of elevating and depressing the tube. Dead space areas can be determined only with an accurate contour map. Trajectories for all charges, low- and high-angle fire, must be considered in the computation of dead space. Dead space is a more serious problem for guns than it is for howitzers.

24-36. Limits

The near limit for any dead space area is the grazing point of the trajectory; i.e., the point nearest the battery where the trajectory intersects the ground (fig. 24-4). The far limit is the first point of impact beyond the near limit or grazing point. Additional limits, particularly at very short ranges, may be imposed by the characteristics of the fuze fired. These additional limits are often undeterminable owing to varying factors of the position, weapon, and ammunition. Some examples of possible additional limits due to fuze characteristics are as follows:

- a. VT fuzes require a minimum arming time range, short of which they will not function.
- b. Time fuzes are restricted to the minimum and maximum effective functioning times.

24-37. Determination of Dead Space

Dead space may be determined by a quadrant elevation ray method. The dead space for one ray is determined, and the process is repeated for such additional rays as necessary to clearly indicate the extent of the dead spaces.

a. The procedure for each charge and type of fire is as follows:

- (1) A ray is drawn on a map overlay from the plotted position of the piece through the desired point on the intervening terrain feature. The highest point of the crest considered is determined by inspection. The quadrant elevations of this point and other points on the ray that are 50 to 100 meters beyond the highest point of the crest are determined. The point requiring the greatest quadrant elevation marks the beginning of the dead space and is known as the grazing point.
- (2) The point of impact, or far limit of dead space, is determined by finding a point beyond the crest which requires the same quadrant elevation as the grazing point. The process is one of trial and error. A test point of impact is selected by inspection, based on the range corresponding to the quadrant elevation for the grazing point. The quadrant elevation for the test point is determined. If the quadrant

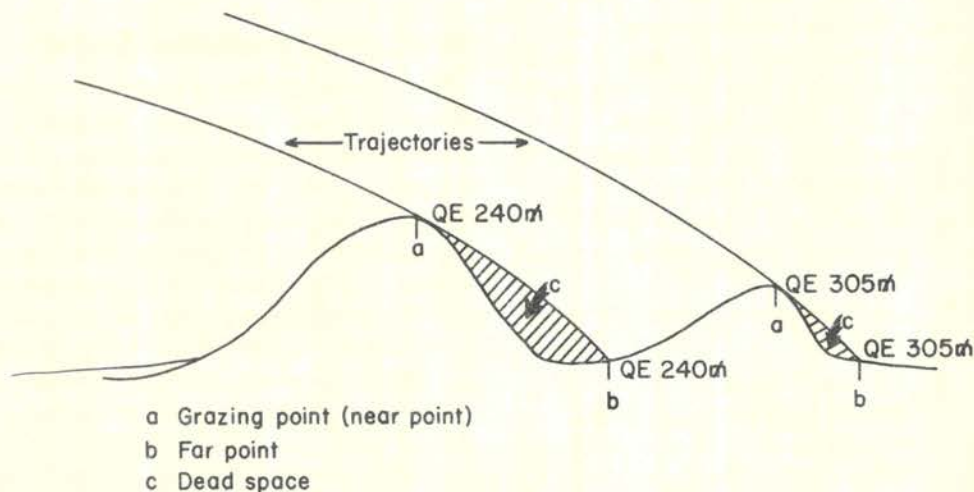


Figure 24-4. Dead space profile.

elevation is less than that for the grazing point, the point is in dead space; if the quadrant elevation is greater than that for the grazing point, the point is beyond dead space. The point of impact can be determined to any desired degree of accuracy by repeating the process.

- (3) When friendly elements occupy the terrain that is being considered, quadrant elevation must be increased by safety factors of 2 forks and 5 meters (or proper vertical clearance for fuze VT) at piece crest range.
- (4) Additional dead space areas along the ray are determined in the same manner as in (1) and (2) above.

b. Adjacent rays should form an angle of no greater than 100 mils except in very symmetrical terrain. In extremely hilly terrain, it may be necessary to determine dead space at 50-mil or smaller increments. The smaller the increments, the more accurately the diagram will reflect true dead space.

Dead space for additional rays is determined in the same manner as in *a* above.

24-38. Dead Space Chart

a. The area of dead space may be outlined on a chart or map by connecting points of determined quadrant elevation, corresponding to the same hill crest, on adjacent rays. Dead space is shaded or labeled.

b. Unless directed otherwise, dead space charts forwarded to higher headquarters need show only dead space areas for low-angle and high-angle fires without regard to charge. Dead space charts for the battalion FDC should be improved as time permits. Improved charts should show charge capabilities as well as dead space areas for low-angle and high-angle fires.

c. In rugged terrain, it may be necessary to determine if a target is in dead space prior to the completion of a dead space chart. The procedure described in paragraph 24-37a is used to determine the dead space on a ray drawn from the battery to the target.

Section XI. MISCELLANEOUS

24-39. Data Sheets

a. *Data Sheet.* Since prearranged fires are fire-for-effect missions, the latest corrections to the chart data must be determined to maintain correct fire commands. The chart and firing data for prearranged fires normally are predetermined and entered on battery data sheets (DA Form 6-14) to facilitate maintaining firing data with current corrections applied. The battery data sheet is usually prepared at the fire direction center; and, if time permits, the data from the battery data sheet are converted to individual piece data and entered on section data sheets (DA Form 6-13) by the computer at the battery fire direction center.

b. *Firing Battery Data Sheet (DA Form 6-14).* A sample firing battery data sheet is shown in figure 24-5 and is self-explanatory except for the following:

- (1) The times entered indicate when firing is started and lifted.
- (2) Time of flight normally is omitted. When time of flight is significant, as it is for fires on positions about to be assaulted by infantry, TOT fire, high-angle fire, or fires at extreme ranges, time of flight is

entered and is used at the battery to modify the listed time of firing.

- (3) Columns for special corrections and zone fire are used only when applicable.
- (4) The remarks column contains any special instructions.
- (5) When new corrections are obtained, the old commands are lined out and the change is entered.

24-40. Fire Capabilities Overlay

The fire capabilities overlay of the battalion shows the area that can be reached by the combined capabilities of the batteries of the battalion as directed. The area that can be reached by two-thirds of the pieces in deflection and range is the fire capability of the battery. The fire capabilities overlay of the battalion, as reported to higher artillery headquarters, may show the area that can be reached by each battery or the combined coverage of all the batteries. The overlay is used in conjunction with the dead space overlay for determining areas not covered by units to fire on targets. For detailed information and illustrations of the fire capabilities overlay, see FM 6-20-2.

FIRING BATTERY DATA SHEET

(FM 6-40)

BATTERY		COORDINATES		ALTITUDE OF BATTERY		TIME		DATE		PAGE NO.							
C		5736038479		397		2000		1 JUN 64		1							
CHART DATA										FIRE COMMANDS							
CONC NO.	COORDINATES	TIME		TIME OF FLIGHT (Sec)	DEFLECTION		RANGE	ALT	SITE DIFF ALT	SP CORR	CHG	CORR	DF	TI	ZONE	QE	REMARKS
		FROM	TO		CORR	CHART DF											
AF	53395						4490	401	+1		4		3278	16.9		286	
2103	39542	0530	0532		L1	3277	280	+4	+5	HE	TI						
							20/R			QX	B(6)						
AF	53843						3970	410	+4				3403			328	
2101	37558	0534	0537		0	3403	324	+13		HE	D						
										QY	B(4)						
AF	50631						7660	437	+6		6		3435	24.0	3 1/2	323	FIRE 5 ELEVATION
2104	36525	0539	0541		L4	3431	314	+40	+3	HE	VT						
200 METER ZONE								20/R		QY	B(2)						
AF	52440						5440	380	-4		4		3284	21.3		360	TOT 0543
2102	37802	0543		20	L2	3282	360	-17	+4	HE	TI						
								20/R		QX	B(5)						

DA FORM 6-14

REPLACES EDITION OF 1 APR 57, EXISTING SUPPLIES OF WHICH WILL BE ISSUED AND USED UNTIL 1 NOVEMBER 1984 UNLESS SOONER EXHAUSTED.

★Figure 24-5. Firing battery data sheet.

★24-41. Universal Transverse Mercator Grid Zone Transformation

a. General. Occasionally, throughout the world operations may take place in an area where artillery is required to fire from one grid zone into another. When this situation occurs it is necessary to transform the coordinates of points and the azimuth of lines from the grid of one zone to the grid of the adjacent zone. This transformation will put the target and the firing unit on a common grid. Transformation of grid coordinates and azimuths can be accomplished by means of computations as outlined in FM 6-2 or graphically as outlined herein.

b. Graphical Zone to Zone Transformation.

(1) *Map construction.* Maps printed by the Army Map Service, Corps of Engineers, that cover an area within 25 miles of a UTM grid zone junction, have printed around the border two sets of gridline numbers. One set is printed in black and the other, corresponding to the adjoining zone, is printed in blue. The marginal information indicates the color that applies to each zone.

(2) *Designation of the primary zone.*

(a) Either one of the two adjoining zones may be designated as the primary zone.

(b) Designation of the primary zone is dependent on one or more of the following:

1. Where the majority of the action is expected to occur.
2. Unit SOP.
3. Directive of the commander.
4. Anticipated future operations.

(c) Generally, unit SOP dictates how the primary zone will be designated and which procedure will be used to determine the grid convergence factor; however, in the absence of an SOP, these decisions are made by the controlling artillery headquarters.

(3) *Preparation of the maps.*

(a) Once the primary zone has been designated, the map is prepared for transformation of data from one zone to another. If more than one map is used, the two maps are fastened together using the common UTM zone junction longitudinal line for orientation.

(b) The FDO and/or a chart operator

(normally the VCO) superimposes the grid of the primary zone over the adjacent zone using a straightedge.

(c) The east-west gridlines are drawn into the adjacent zone by aligning the straightedge with the tick marks around the border and numbered with the appropriate values.

(d) The north-south gridlines are drawn by aligning the straightedge with the appropriate tick marks along the border of the map and numbered with the appropriate values.

Note. The superimposed grid should be drawn using a distinctive colored line to facilitate rapid transformation of data and to reduce the possibility of error.

(4) *Determination of the grid convergence factor.* The grid convergence factor is used to convert an azimuth from the grid of one grid zone to that of an adjacent grid zone. This factor is determined from the marginal information of the maps or from a current Army Ephemeris.

(a) The marginal information printed on maps by the Army Map Service contains the grid convergence (grid declination) at the center of the map sheet. When the map sheet is within 25 miles of a grid junction, the grid convergence for each zone is given. One convergence is easterly and one westerly. The grid convergence factor is the sum of these two figures expressed to the nearest 10 mils.

(b) The convergence factor may also be computed using table 15, TM 6-300-(current year) (Army Ephemeris).

1. Determine the northing coordinate of the firing unit using the grid of both the primary and the secondary zones.

2. Add these two values and divide by 2 to obtain the average northing. This is the argument for entry into the tables.

3. Enter the appropriate table for the latitude of the area. Use the average northing coordinate and enter column N to the nearest listed value and determine the correction factor in mils from column G.

(c) When this factor is used to transform the grid azimuth from one UTM zone to another, the sign used is determined by the following chart:

<i>Northern Hemisphere</i>	<i>Southern Hemisphere</i>
----------------------------	----------------------------

East to West, sign is -	East to West, sign is +
West to East, sign is +	West to East, sign is -

Note. When in the southern hemisphere, the average northing coordinate must be subtracted from 10,000,000 before entering the table.

c. Gunnery Procedures.

(1) *General.* The fire direction procedures necessary to rapidly calculate accurate firing data across a UTM Grid Zone junction are based on three primary considerations.

(a) Standard or normal "call for fire" procedures are utilized.

(b) The firing charts should remain as simple and uncluttered as possible.

(c) The system should be capable of easily controlling a number of firing units.

(2) *Observer procedures.* The observer sends the target location in the normal manner using coordinates, polar plot, or shift from a known point. His map will require no superimposed grid lines and his azimuth measuring instruments should be declinated for the same grid line as the location used in his call for fire.

(3) *FDC procedures.*

(a) In the FDC, all coordinates and azimuths entered into FADAC should be in terms of the primary zone.

(b) The charts used either as the primary method to compute firing data or in conjunction with FADAC should also be in terms of the primary zone.

(c) The battle map should have the primary zone superimposed over the secondary zone and will be used to convert coordinates from secondary zone into primary zone coordinates. This is accomplished by first plotting the coordinates, using the printed grid lines of the secondary zone, and then reading the new coordinates for this point using the superimposed grid lines of the primary zone.

(d) The grid convergence factor is determined to the nearest mil and expressed to the

nearest 10 mils. It is generally determined only once for a firing position.

(4) *FDC operation.* When a target is received at the FDC which falls in the primary zone, the mission is processed using standard gunnery procedures as outlined herein. The following procedure modifications are used only when the target falls in the secondary zone.

(a) *Target location by coordinates.*

1. Target coordinates in the secondary zone are received by the FDC.

2. The VCO plots them on his battle map and reads the corresponding primary zone coordinates from the map.

3. The FADAC operator (HCO) enters (plots) these coordinates.

4. The computer applies the grid convergence factor to the reported OT azimuth and announces the converted azimuth to the FADAC operator (HCO).

5. At this point, the target location is completely transformed into the primary zone and the remainder of the mission is computed in the standard manner.

(b) *Target location by polar plot or shift from a known point.*

1. An observer in the secondary zone sends a fire mission using either of the above methods.

2. In order to use these methods of target location, the observer's location or the known point must be stored in the FADAC (plotted on the chart). Therefore, the coordinates have already been converted to the primary zone and the FADAC operator simply recalls the location (HCO moves the RDP to the plot on the chart).

3. The computer applies the grid convergence factor to the observer's OT azimuth and announces the converted azimuth to the FADAC operator (HCO).

4. Again, the target location is completely transformed into the primary zone and the remainder of the mission is processed in the standard manner.

CHAPTER 25

FDC PROCEDURES FOR HIGH-ANGLE FIRE

25-1. General

a. Fire delivered at elevations in excess of the elevation corresponding to the maximum range for each charge is called high-angle fire. High-angle fire is used to fire into or out of deep defilade. It may be requested by the observer or ordered by the S3.

b. Most howitzers are capable of attacking targets effectively with high-angle fire. High-velocity weapons (guns) normally are not used for high-angle fire because their high velocities result in extremely high maximum ordinates, long times of flight, and large probable errors. Even with howitzers, high-angle fire results in high maximum ordinates and correspondingly long times of flight. Small changes in range cause relatively large changes in times of flight.

c. To assist the observer in identifying his rounds, FDC personnel will announce SPLASH 5 seconds prior to impact. They may give the time of flight when they announce SHOT. Time of flight must always be given to an air observer. It may be coded to provide security for the battery location.

d. The principal difference between low-angle fire and high-angle fire is that in high-angle fire an *increase* in elevation will cause a *decrease* in range.

25-2. Fire Order

When high-angle fire is to be used, the S3 will omit the charge from the fire order. The charge is determined by the adjusting battery computer (para 25-4). If the decision to fire high-angle is made by the S3, based on his estimate of the situation, the words "high angle" will be substituted in the fire order for charge; however, if high-angle fire is included in the observer's call for fire, it need not be repeated in the fire order. If appropriate, the command INCLUDE SITE follows or replaces HIGH ANGLE (para 25-7).

25-3. Fire Commands

a. Fire commands for high-angle fire must include the command HIGH ANGLE to alert the gun crews that a high-angle mission is to be fired.

This command follows the ammunition lot number. All other commands for a precision mission and for the adjusting battery for an area mission are the same as those for low-angle fire.

b. The charge, which may change during the adjustment, the fuze setting (VT fuzes), and the quadrant elevation, which cannot be used until the piece is to be loaded, are omitted in the initial fire commands to the nonadjusting batteries. For example—

<i>Adjusting battery</i>	<i>Nonadjusting battery</i>
BATTERY ADJUST.	BATTERY ADJUST.
SHELL HE.	SHELL HE.
LOT XY.	LOT XY.
HIGH ANGLE, CHARGE	HIGH ANGLE (charge is omitted).
4.	
FUZE QUICK.	FUZE QUICK.
CENTER 1 ROUND, BATTERY 4 ROUNDS IN EFFECT.	BATTERY 4 ROUND.
DEFLECTION 2992.	DEFLECTION 2847.
	WAIT, OUT (further commands are not given until fire for effect).

QUADRANT 1173.

c. The charge, the fuze setting (if any), and the quadrant elevation for the nonadjusting batteries are determined and announced when fire for effect is ordered.

25-4. Selection of Charge

In selecting the charge to be used, the adjusting battery computer, supervised by the S3, selects the charge that is least likely to require changing due to subsequent corrections from the observer. Depending on the cannon used, there is some degree of overlap in ranges covered by various charges. If there appears to be a choice between two charges, the lower charge is selected to reduce time of flight and tube wear. However, during an adjustment it may be necessary to change charges if the observer's initial target location was inaccurate.

25-5. Fuze

The most effective fragmentation of any burst occurs in a plane approximately at right angles to the line of fall. This fragmentation is almost parallel to the ground with high-angle fire. Consequent-

ly, if time fuze is fired, a very slight error in height of burst may cause the burst to occur so high as to cause significant loss of fragmentation effect. Because of the large height of burst probable error, time fuze is not normally employed with high-angle fire. The steep angle of fall eliminates the possibilities of ricochet fire. Fuze quick or fuze VT normally is used.

a. Fuze quick is very effective when used in high-angle fire against personnel in the open because the projectile is almost vertical at the instant of detonation. Since the side spray of the burst contains most of the fragmentation, the effect is a spray in all directions out from the point of impact approximately parallel to, and very near, the ground.

b. The maximum lethality against personnel in the open is attained with a high-explosive projectile and fuze VT. This combination has the advantages of a lateral spray effect obtained with fuze quick and the effectiveness of a very low airburst.

c. Because the side spray is horizontal, high-angle fire can be expected to be less effective than low-angle fire against personnel in trenches or foxholes, regardless of the fuze used.

25-6. Deflection

a. Drift is large in high-angle fire and increases with an increase in time of flight; thus, in high-angle fire, drift increases as elevation increases and range decreases.

b. Drift changes too rapidly to permit use of a deflection correction scale as used in low-angle fire. Because drift changes an appreciable amount for a relatively small range change, a correction to compensate for drift, which is determined at the elevation to be fired, is included in each deflection to be fired. Since drift is to the right, the correction is to the left and is always applied to the sum of the chart deflection and the deflection correction (if any).

Example: 155-mm howitzer, charge 5 green bag, high-angle.

Range	Elevation	Chart deflection	Deflection correction	Drift correction	Piece deflection
8500-----	1060	3200	0	L45	3245

25-7. Site

a. For observed fires, site, because of the large angle of fall, normally can be ignored if the angle

of site is no larger than plus or minus 30 mils. However, site must always be included in registrations, in transfer fires, and for massing on a target when one battery has adjusted. Whether site is to be included is decided by the S3 and announced in the fire order. If the S3 desires that site be computed and used in the mission, the command INCLUDE SITE will follow HIGH ANGLE in the fire order. If HIGH ANGLE is not given in the fire order, the command INCLUDE SITE replaces it. Omission in the fire order of the command INCLUDE SITE means that site is to be ignored. Regardless of whether or not site is included in fire commands, the height-of-burst correction (20/R), used with fuze VT in low-angle fire, is *not* used in high-angle fire because the descending branch of the trajectory is nearly vertical.

b. The GST does not include site scales for high-angle fire; however, the C and D scales of any GST can be used to compute the angle of site. An increase in angle of site requires a decrease in quadrant elevation, because, in high-angle fire, the complementary angle of site factor is always greater than 1 mil and always has a sign opposite that of the angle of site. If the angle of site is plus, the comp site is minus; if the angle of site is minus, the comp site is plus. The comp site factor is a function of elevation and is determined from the Supplementary Data table of the firing tables.

c. When the tabular firing tables are used to compute site, complementary angle of site is added algebraically to the angle of site and always results in a site which is opposite in sign to the angle of site.

d. A special site scale has been included on high-angle graphical firing table to simplify the determination of site when high-angle fire is being used. The site scale is located just below the elevation scale. This scale is referred to as the 10-mil site scale. The readings obtained from this scale give the site for 10 mils' angle of site at the elevation and charge that is being used. The site for any point is determined by dividing the angle of site to that point by 10 and multiplying the quotient by the factor read from the 10-mil site scale. The site derived from the 10-mil site scale will be slightly less accurate than the value computed from the tabular tables. The 10-mil site factor, considered negative, when multiplied by the angle

of the site and divided by 10, will produce the proper sign and amount of the site. The sign of the site will be opposite that of the angle of site.

Example: 155-mm howitzer M109, charge 5 green bag, using GFT.

Chart range.....	8,500 meters.
Elevation corresponding to chart range.	1,060 mils.
Altitude of battery.....	400 meters.
Altitude of target.....	509 meters.
Vertical interval.....	+109 meters.
Angle of site (C and D scales, GST)....	+13 mils.
10-mil site factor (GFT).....	-4.3.
Site ($13/10 \times (-4.3)$).....	-6 mils.
Quadrant elevation ($1060 + (-6)$)....	1,054 mils.

e. If a change in charge is required during the conduct of the mission, site should be recomputed for the new charge.

25-8. Precision Registration

Precision registrations using high-angle procedures present only two major differences from low-angle procedures. These differences and the corresponding methods to be applied are as follows:

a. Elevation and range have a reverse relationship. Therefore, application of fork is opposite that used in low-angle fire. The same holds true for the application of elevation change.

b. High-angle fire introduces large amounts of drift into the trajectory. Additionally, this value of drift changes with each small change in range. This increased rate of change in drift introduces a unique situation whereby deflections fired at various elevations contain different amounts of drift. In order to minimize the error caused by this condition special consideration must be given to the computation of correct deflection.

(1) During the adjustment phase no use is made of line shots.

(2) No attempt is made to change the value of deflection until after the full even fork bracket has been established. At this time the normal procedure would apply. Definite deflection spottings determined at either or both ends of the fork bracket may be utilized.

c. Site must be algebraically subtracted from the adjusted quadrant elevation to determine the adjusted elevation. The correct site can only be derived by successive approximation, since comp site is a function of elevation and not of chart

range. Correct site is determined when the site computed agrees within 1 mil of the previously computed site. The last site computed is the correct site.

Example: Determination of adjusted elevation by successive approximation, 155-mm howitzer M109, charge 4 green bag (fig. 25-1) (DA Form 6-12, Record of Precision Fire).

Angle of site.....	+8 mils.
Adjusted QE.....	1,193 mils.
Site fired during registration.....	-2 mils.
10-mil site factor corresponding to elevation 1,195.	-1.8 mils.
First apparent site ($8/10 \times (-1.8)$)	-1 mil.
= -1.4.	
First apparent site agrees within 1 mil of site fired.	
Adjusted elevation.....	1,194 mils.

d. GFT settings for high-angle fire are established in the same manner as those for low-angle fire. For example in *c* above, the GFT setting is GFT B: Charge 4, lot ZT, range 5680, elevation 1194.

e. Standard transfer limits are not applicable to high-angle fire because of the short range span of each charge. Corrections are considered valid for the charge used to determine the corrections and for other charges as shown in table 25-1. In cases in which a desired charge is on the reverse side of the GFT, corrections can be transposed by establishing an elevation gageline corresponding to the total range correction at the GFT setting range.

f. The adjusted deflection is equal to the correct deflection plus the correction for lateral base piece

Table 25-1. Transfer Limits, High Angle

Weapon	Charge registered with	Transfer limits
105-mm how---	1, 2, 3, 4, 5.	All ranges, charges 1 through 5.
	6.....	Charge 6 only, $\pm 1,500$ meters.*
	7.....	Charge 7 only, $\pm 1,500$ meters.*
155-mm how and 8-inch how.	1, 2, 3, 4...	All ranges, charges 1 through 5.
	5.....	Charge 5 only, $\pm 1,500$ meters.*
	6.....	Charge 6 only, $\pm 1,500$ meters.*
	7.....	Charge 7 only, $\pm 1,500$ meters.*

* $\pm 2,000$ meters for registration point ranges greater than 10,000 meters.

RECORD OF PRECISION FIRE

(FM 6-40)

Date and time 10 JUNE 66, 0800		Observer 44		Adjusting point R56 PT 1		Battery B		
GFT setting GFT B :chg 4 ,lot ZT ,rg 5680 ,el 1194 ,ti						Deflection correction R5		
Chart data		Initial fire commands						
Deflection 3252	Corr L67	BP Adjust						
Range 5680	El 1189	Sh NE	Lot ZT					
Adjusted data		Si -2(451=+8)	Chg 4 Fz 0					
Deflection 3247	S/2= 2	MF BP	①					
Elevation 1194	F= 7	Df 3319						
Time	F/2= 4	QE 1187	Angle T 430					
Round no	Chart df	Df fired	Chart range	Time fired	El or QE fired (-2)	Observer sensing or corrections	FDC sensings	
							Range	Deflection
①	3252+167	3319	5680		1187	L30-200		
②	3240+170	3310	5510		1201	+100		
③	3244+168	3312	5600		1194	+50, FFE		
④	3246+167	3313	5660		1190	+R	+	?
⑤		(3313)			1198	-R	-	R
⑥		3315			1194	-LN	-	R
⑦		3317			1194	-R	-	R
⑧		3319			1194	+LN	+	L
⑨		(3318)			1190	+R	+	CORR
⑩					1190	+LN	+	
11					EM			
12	MEAN QE			1192.0		CORR DF		3318
13	EI CHANGE $(\frac{4-2}{2 \times 6}) \times 7$			+1.2		B.P. DISPLACEMENT		R3
14	ADJ. QE			1193.2	= 1193	DRIFT CORR (EL 1194)		L68
15	SITE FIRED				-(-2)	ADJ DF		3247
16	1st App EL				1195	CHART DF		3252
17	10% SI FACTOR AT EL 1195		-1.8			DF CORR		R5
18	1st App Site (B/10 x -1.8)				-1			
19	AGREES WITHIN 1 mil OF SITE FIRED							
20	ADJUSTED EL				1194			
21								
22								
23								
24								

DA FORM 6-12
1 OCT 64REPLACES DA FORM 6-12, 1 APR 57, EXISTING SUPPLIES OF WHICH
WILL BE ISSUED AND USED UNTIL 1 OCT 68 UNLESS SOONER EXHAUSTED.

Figure 25-1. Record of precision registration, high-angle fire

displacement minus the drift correction corresponding to the adjusted elevation. The deflection correction is determined by subtracting the chart deflection from the adjusted deflection.

Example: 155-mm howitzer M109, charge 4 green bag, high-angle.

Adjusted elevation	1,194 mils.
Correct deflection	3,318 mils.
Correction for lateral base piece displacement.	R3 mils.
Drift correction corresponding to adjusted elevation.	L68 mils.
Adjusted deflection (3318 + R3 - L68).	3,247 mils.
Chart deflection to registration point.	3,252 mils.
Deflection correction (3247-3252)	R5 mils.

g. If no high-angle registration has been conducted, a deflection correction of zero will be used. If a charge other than that with which the registration was conducted is to be fired, the deflection correction for the charge nearest the charge to be fired is used.

★25-9. Preparation of Graphical Equipment

Graphical equipment is prepared for high-angle fire missions in the same way as for low-angle fire missions except for the handling of the deflection correction. The deflection correction for each charge is written on the GFT adjacent to the data for that charge (fig. 25-2).

25-10. Data for Replot

a. The purpose of replot in high-angle fire is the same as that in low-angle fire (para 20-15).

★b. Regardless of whether site is included during the adjustment, the correct site must be algebraically subtracted from the adjusted (fire-for-effect) quadrant elevation to obtain the adjusted (fire-for-effect) elevation. The range at which the target is plotted is determined from the adjusted elevation. During the adjustment, the 10-mil site factor may change considerably and will result in an effective site at the end of the adjustment that is different from that used in the initial firing data. This error must be corrected if the target is to be plotted at its correct range.

Example: 155-mm howitzer M109, GFT setting (from prior registration) is GFT B: Charge 5, lot WY (green bag), range 7050, elevation 1145.

Angle of site	+20 mils.
Adjusted QE	1,162 mils.
10-mil site factor corresponding to elevation 1162.	-2.0 mils.
First apparent site (+2.0 × (-2.0) = -4.0).	-4 mils.
First apparent adjusted elevation (1162 - (-4)).	1,166 mils.
10-mil site factor corresponding to elevation 1166.	-2.0 mils.
Second apparent site ((+2.0) × (-2.0) = -4.0).	-4 mils.
Second apparent site agrees with first apparent site.	
Adjusted elevation (1162 - (-4)).	1,166 mils.
Range corresponding to elevation 1166 (use GFT setting) used in replotting target.	6,780 meters.

c. After the adjusted elevation has been determined as described in b above, the deflection correction for the charge (or, if no correction has been determined for the charge fired, the correction from the nearest other charge which does have a correction) and the drift correction are subtracted from the fire for effect piece deflection. If no deflection correction has been determined, the deflection for replotting will be obtained by subtracting only the drift correction from the fire for effect piece deflection. The result is the deflection for plotting the target.

Example: 155-mm howitzer M109, charge 5 green bag.

FFE piece deflection	3,245 mils.
Adjusted elevation	1,166 mils.
Drift correction corresponding to adjusted elevation.	L62 mils.
Deflection correction for charge 5.	L15 mils.
Total deflection corrections (L62 + L15).	L77 mils.
Replot deflection (3245 - L77)	3,168 mils.

d. If the terrain is rugged or if a large range change has been made since the angle of site was first computed (the angle of site may be first computed at the beginning of the mission or at the onset of determining replot data), the angle of site is recomputed for the replotted lo-

cation of the target. The new map altitude is used in determining the new angle of site. If the new angle of site differs by more than 1 mil from that angle of site previously computed, a new adjusted elevation and a corrected range for replotting the target must be obtained. This process is repeated until the correct angle of site (one that agrees with 1 mil of that previously computed) and adjusted elevation are determined. Data for replot are reported by using the same procedures as used for low-angle fire except that the type of fire and charge used are included; for example, coordinates _____, altitude _____, fuze _____, high-angle, charge _____, target _____, high-angle, charge _____, target _____.

25-11. Massing and Transfers

a. The high maximum ordinates and long times of flight encountered in high-angle fire make massing or transfer of fire less reliable than with low-angle fire. However, under stable weather conditions, successful transfers of fire within a single charge are practicable. The small area of range covered by each charge prevents establishment of definite transfer limits. Consequently, every effort should be made to obtain observation and to adjust each battery that is to fire on the target.

b. If several batteries are to mass on a target when only one battery is to adjust, site should be computed at the initial range for each battery. Site should be recomputed for the nonadjusting batteries whenever it is necessary to recompute site for the adjusting battery (e.g., when the adjusting battery changes charges) or should be recomputed for an individual nonadjusting battery when it changes charges.

c. During an adjustment, the 10-mil site factor may change considerably. This change will result in a site at the end of the adjustment that differs from that used in the initial commands. However, the error in range due to

false site for the adjusting battery will be essentially the same range error required for the nonadjusting batteries to compensate for their false sites.

25-12. Duties of Fire Direction Personnel

The duties of fire direction personnel in high-angle fire are the same as those in low-angle fire except for minor modifications as stated in *a* through *c* below.

a. The S3 must include in the fire order the command HIGH ANGLE in place of the command CHARGE. He must also decide whether to include site.

(1) When adjustment is required prior to massing the battalion and only one battery is to adjust, the battery that is centrally located should normally be designated as the adjusting battery to eliminate large differences in range.

(2) For area missions to be fired by more than one battery, all batteries to fire should fire at center range, since dispersion in range will usually result from the effects of weather and the probable use of different charges by each battery.

★*Example:* High-angle fire roder. BAT-TALION, BRAVO, USE GFT, LOT ZT, HIGH ANGLE, INCLUDE SITE, FUZE VT IN EFFECT, 2 ROUNDS, TARGET ALFA FOX-TROT 2604.

b. The vertical control operator computes and announces angle of site, rather than site, when the fire order contains the command INCLUDE SITE.

c. The computer must—

(1) Select the charge to be fired.

(2) Combine the drift correction, the deflection correction (if known), and the chart deflection and announce the algebraic sum as deflection.

(3) If the fire order so designates, compute the site and add it to elevation to determine quadrant elevation.

CHAPTER 26

OBSERVED FIRING CHARTS

Section I. INTRODUCTION

26-1. General

Immediate delivery of supporting fires must not be delayed by an incomplete survey or lack of suitable maps. When survey control and maps are not available, an observed firing chart is constructed. An observed firing chart is a chart on which the relative locations of the battery position(s) and targets are established by the adjustment of fires. An observed firing chart normally is constructed on a grid sheet.

26-2. Initial Observed Firing Charts

a. If the battery initial chart is an observed firing chart, grid coordinates of the battery center are assumed and the battery center is plotted on a grid sheet. Direction of fire and a safe range are determined by the S3 based on his knowledge of the situation. A deflection index corresponding to the direction of fire is constructed on the grid sheet.

b. The observer's call for fire must include MARK CENTER OF SECTOR, if no other method of target location is available. The data for the initial round are determined from the estimated direction and range to the center of sector. Subsequent firing data are based on the observer's corrections. Fire direction proce-

dures in the conduct of fire are generally the same as those used with a surveyed firing chart. After the mission has been completed, the observer may use the target as a known point in reporting other target locations.

c. As long as the ballistic variables of weather, materiel, and ammunition remain constant, any previously fired target may be re-fired by using the same data. If the ballistic conditions do not remain constant, inaccuracies will occur in subsequent firing. A registration should be conducted as soon as possible to provide a means of determining subsequent corrections and to increase the accuracy of relative locations.

d. Targets fired on should be plotted on the firing chart to provide additional means of target location. The last pinhole will provide sufficient accuracy and should be noted with tick marks and a target number.

e. In situations where survey does not exist and maps are either inaccurate or nonexistent, the countermortar or counterbattery radar can be used to place the artillery battalion on a common grid and provide common direction for the massing of fires. For detailed information, see paragraphs 26-24, 26-25, and FM 6-161.

Section II. BATTERY OBSERVED FIRING CHARTS

26-3. General

a. After the registration has been completed, assumed grid coordinates and altitude are assigned to the registration point. Based on the adjusted data, the location of the battery with respect to the registration point is determined. The battery is plotted on the back-azimuth of the azimuth of fire. If an impact registration is

fired and site cannot be approximated, the battery is plotted at a range corresponding to the adjusted quadrant elevation. If a time registration is fired, the range corresponding to the adjusted time is used. The derived site is used to determine the relative altitude of the battery. The deflection index is constructed at the adjusted deflection and a deflection correction

scale is prepared to preclude applying large deflection corrections.

b. One of the sources of inaccuracies in observed firing charts is the inclusion of false site and its corresponding range error into the polar plot range. Errors due to false site can be reduced by using time fuze and selecting the charge which minimizes the height of burst probable error.

c. The battery observed firing charts may be consolidated into a battalion chart if all batteries register on the same registration point (para 26-11-26-14) or survey ties the batteries together with respect to one another (para 26-19).

26-4. Determination of Direction for Polar Plotting

a. At the completion of the registration, the battery executive officer measures the azimuth or the orienting angle (if an orienting line has been established).

b. If an orienting line has been established, the azimuth from the battery to the registration point is determined by subtracting the orienting angle measured by the battery executive officer from the azimuth of the orienting line. If there is no orienting line, the azimuth measured by the battery executive officer is used.

c. The direction for polar plotting the battery is the back-azimuth of the direction determined in b above.

26-5. Determination of Range and Altitude, Percussion Plot

a. When maps and survey data are not available the determination of accurate site is impossible. However, every effort must be made to determine the approximate site. If the determination of even an approximate site is not feasible, the site is assumed to be zero. The range for polar plotting is the range corresponding to the adjusted elevation (adjusted QE minus the site); the hairline of the GFT is placed over the adjusted elevation and the range is read under the hairline.

b. The vertical interval between the battery and the registration point should be estimated

if possible. The estimated vertical interval is used to successively approximate site in the following manner:

(1) Determine range corresponding to the adjusted quadrant.

(2) Use this range and estimated vertical interval to compute a first apparent site.

(3) Apply the site to the adjusted QE to determine an elevation.

(4) Determine range corresponding to this elevation.

(5) Use this range and estimated vertical interval to compute a second apparent site.

(6) Continue successive approximation until the site agrees within 1 mil of the previously computed site. The last site computed is used to determine the adjusted elevation and the back plot range.

(7) Apply the vertical interval to the assumed altitude of the registration point to determine the altitude of the battery.

26-6. Determination of Range and Altitude, Time Plot, Site Unknown

a. The major sources of error in range in an observed firing chart, percussion plot, are the lack of an accurate site and the effects of unknown variations from standard conditions. If the site is unknown or incorrect, the derived adjusted elevation is in error by the amount of the error in site. To derive the polar plot range from a false elevation introduces a false range. However, the effect of site on the fuze setting is usually small. Therefore, the adjusted time can be used as a good indicator of the adjusted elevation and the polar plot range.

b. A site may be derived by subtracting the elevation corresponding to the adjusted time (minus the average fuze correction, if any) from the adjusted quadrant elevation. The vertical interval is determined from the GST by multiplying the polar plot range by the derived site. The altitude of the battery is then determined by applying the vertical interval to the assumed altitude of the registration point.

★*Example:* A 155-mm howitzer M109 battery using charge 5 has registered on a registration point.

Adjusted QE	315 mils.
Adjusted time	20.4
Average fuze correction	None.
Range corresponding to time 20.4 (polar plot range).	6,140 meters.
Elevation corresponding to time 20.4.	305 mils.
Derived site (315-305)	+10 mils.
Vertical interval (+10×6140) (GST).	+55 meters.
Altitude of registration point (assumed).	400 meters.
Altitude of battery (400-55)	345 meters.

c. When an average fuze correction is known, the accuracy of site and elevation will be increased by determining the adjusted elevation in the following manner:

(1) Subtract the average fuze correction from the adjusted time.

(2) Read the adjusted elevation corresponding to the adjusted time.

26-7. Determination of Range and Altitude, Time Plot, Site Known

a. If an approximate site is known, the polar plot range is determined in the same manner as described in paragraph 26-6.

b. The known site is used to determine the altitude of the battery.

c. The elevation is derived by subtracting the known site from the adjusted quadrant elevation.

26-8. Determination of Site by Firing (Executive's High Burst)

An appropriate site approaching survey accuracy may be determined by firing a modified high-burst registration after the completion of a precision registration.

a. Fuze setting (time), for a given charge, is a function of elevation plus the complementary angle of site. Therefore, if the fuze setting is constant but the quadrant elevation is varied, the *elevation plus comp site* to each of the resulting points of burst is constant.

b. If, after a registration, a group of rounds is fired with the adjusted time but with a quadrant elevation large enough to raise the point of burst so that the burst is visible from the gun position, the angle of site to the burst can

be measured. The measured angle of site is subtracted from the fired quadrant elevation. The result is the elevation plus comp site to the burst ($QE = \text{elevation} + \text{angle of site} + \text{comp site}$). The elevation plus comp site thus determined corresponds to the fuze setting fired (adjusted time) and is equal to the elevation plus the comp site to the registration point. Subtracting the elevation plus comp site from the adjusted quadrant elevation for the registration point gives the angle of site to the registration point. The angle of site thus determined and the range corresponding to the adjusted time can be used to compute the vertical interval and the site to the registration point.

c. The procedure for conducting an executive's high burst is as follows:

(1) After the time registration, the S3 sends the command OBSERVE HIGH BURST, MEASURE ANGLE OF SITE, 3 ROUNDS, ADJUSTED DEFLECTION (so much), ADJUSTED TIME (so much), ADJUSTED QUADRANT ELEVATION (so much) to the battery executive officer. The executive officer estimates the increase in site necessary to cause the bursts to be visible from the battery position and adds it to the announced quadrant elevation. He then has the base piece fire three rounds using the adjusted deflection, the adjusted time, and the increased quadrant elevation. The executive officer measures the angle of site to each burst with an aiming circle or BC scope (battery commander's telescope) set up in the vicinity of the base piece. He then reports the average observed angle of site and the quadrant elevation fired.

(2) The FDC determines the site to the registration point, the adjusted elevation, and the vertical interval between the battery and the registration point in the following manner:

(a) The elevation plus comp site for the executive's high burst is determined by subtracting the average angle of site reported by the battery executive officer from the quadrant elevation fired. The elevation plus comp site thus determined is also the elevation plus comp site to the registration point.

(b) The angle of site to the registration point is determined by subtracting the eleva-

tion plus comp site from the adjusted quadrant elevation to the registration point.

(c) The C and D scales of the GST are used to determine the vertical interval between the battery and the registration point by multiplying the angle of site ((b) above) by the range to the registration point in thousands to the nearest 10 meters.

(d) Site to the registration point may then be determined by dividing the vertical interval by the range to the registration point, using the appropriate site range scale of the graphical site table.

(e) The adjusted elevation may be derived by subtracting the site ((d) above) from the adjusted quadrant elevation.

★*Example:* A 155-mm howitzer M109 was registered on a point with charge 5. The adjusted data for the registration point included adjusted time (fz M564) 19.7 and adjusted quadrant elevation 302 mils. The report from the executive officer following the high burst was OBSERVED ANGLE OF SITE +14; QUADRANT FIRED 325. The registration point site, adjusted elevation, and vertical interval are determined as follows:

★Range corresponding to	5,960 meters.
adjusted time (19.7).	
QE fired for high burst	325 mils.
Average angle of site to high burst.	+14 mils.
Elevation plus comp site to high burst.	311 mils.
Adjusted QE to registration point.	302 mils.
Elevation plus comp site to registration point.	311 mils.
Angle of site to registration point (302-311).	-9 mils.
Vertical interval (-9×5.96 , C and D scales, GST).	-54 meters.
Site ($-54/5960$, GST)	-10 mils.

Adjusted elevation (302- 312 mils. (-10)).

Note. If graphical equipment is not available, site may be determined in the following manner:

Comp site factor for	-0.070 mil.
range 5960 (6000).	
Comp site (9×-0.070)	-0.6 mil.
Site (-9) + (-0.6) =	
(-9.6).	-10 mils.

d. After understanding the theory on which the determination of site by firing is based, it may be easier to use the "got minus asked for" rule (fig. 26-1) to compute the angle of site. For the problem in c above, if the angle of site to the registration point had been zero, the increase in quadrant elevation to 325 (increase of +23 mils "asked for") would have caused the bursts to occur at a measured angle of site +23 mils. Since the bursts actually occurred at a measured angle of site +14 mils ("got"), the registration point angle of site must be -9 mils. The formula (fig. 26-1) used is angle of site to registration point = got minus asked for = +14 - (+23) = -9. This angle of site must be converted to site as above.

26-9. Deflection Index

After the battery has been polar plotted on the chart, the deflection index is constructed at the adjusted deflection.

26-10. Graphical Firing Table Settings

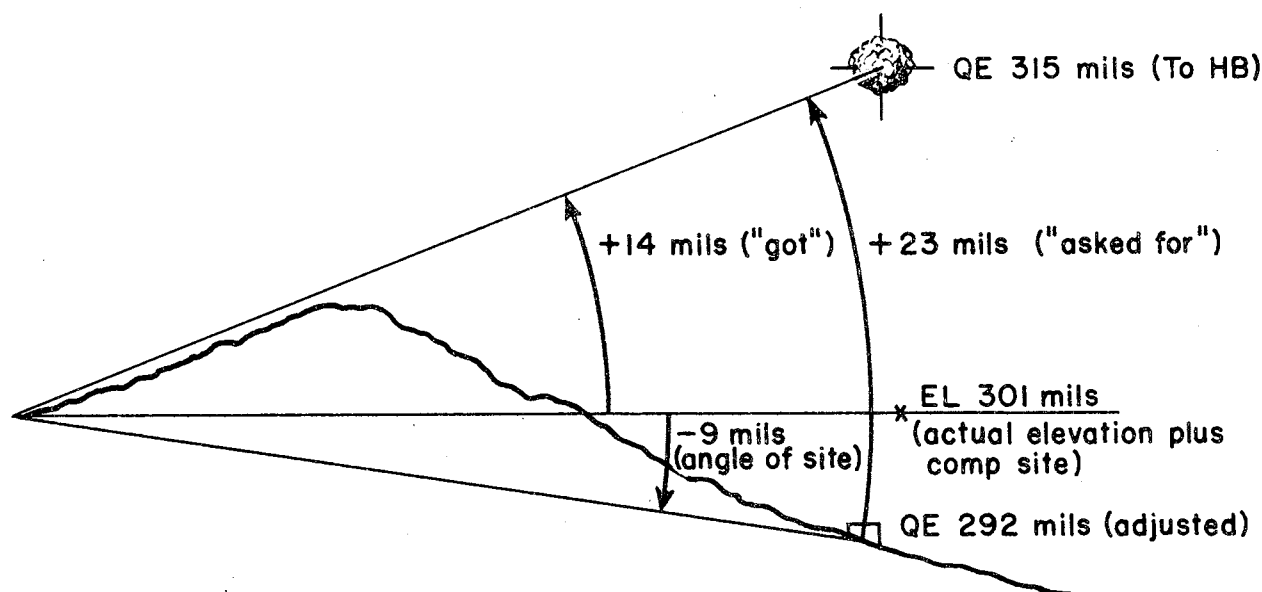
The GFT setting for a battery using an observed firing chart is made in the usual manner. The hairline is placed over the chart range (polar plot range). The elevation gage-line (if any) is drawn through the adjusted (derived) elevation. The time gage-line is drawn through the adjusted time.

Section III. BATTALION OBSERVED FIRING CHART

26-11. General

a. A battalion observed firing chart is based on the concept that points located with respect to a common point are located with respect to each other. If each firing battery of a battalion has registered on the same registration point

and has been located on the firing chart (para 26-3-26-10), the batteries are then considered to be plotted in correct relationship to each other. Because the batteries are located correctly with respect to each other, the fires of the battalion may be massed on any target lo-



$$\text{Got} - \text{asked for} = +14 - (+)23 = -9 \text{ mils angle of site}$$

★Figure 26-1. "Got-asked for" diagram.

cated by the adjustment of one of the batteries.

b. The principles involved in the construction of a battalion observed firing chart are the same as those for the construction of a battery observed firing chart. This section will describe the techniques used in the construction of the battalion chart.

26-12. Determination of Direction for Polar Plotting

The direction used to polar plot each battery is determined in the manner prescribed in paragraph 26-4.

26-13. Determination of Range and Altitude Percussion Plot

a. Range and altitude for each battery may be determined in the manner described in paragraph 26-5.

b. If the relative altitudes of the batteries of the battalion can be determined, the accuracy of the firing chart can be improved. One battery is selected as a reference battery and its polar plot range and altitude are determined in

the manner described in paragraph 26-5. The altitude and range for each of the other batteries is determined in the following manner:

(1) The vertical interval from the battery in question to the registration point is computed by applying the difference in altitude between the battery in question and the reference battery to the vertical interval from the reference battery to the registration point.

(2) An apparent site for the battery in question is computed by using the vertical interval ((1) above) and the range corresponding to the adjusted quadrant elevation for the battery.

(3) An apparent-adjusted elevation is derived by subtracting the apparent site from the adjusted quadrant elevation.

(4) A new site is then computed by using the vertical interval and the range corresponding to the apparent adjusted elevation, and a new adjusted elevation is determined. If the new site varies by more than 1 mil from the apparent site, successive approximation is continued until two successive sites agree or agree within 1 mil.

(5) When the apparent site agrees within 1 mil of the last site computed, the adjusted elevation is determined. The polar plot range is the range corresponding to this adjusted elevation.

Example: The batteries of a 155-mm howitzer M109 battalion have registered on a common registration point with charge 5 green bag. The assumed altitude of the registration point and Battery B, the reference battery, is 500 meters. The battery vertical intervals with reference to Battery B are as follows: Battery A, -48 meters; Battery C, +34 meters. The adjusted data included the following:

Battery	Adjusted QE
A -----	337
B -----	323
C -----	320

Determine the battery altitudes and polar plot ranges as follows:

(1) *Battery B.*

Altitude of registration point 500 meters.
 Altitude of Battery B ----- 500 meters.
 Vertical interval ----- Zero.
 Site ----- Zero.
 Adjusted elevation (323-0) 323 mils.
 Range corresponding to adjusted elevation, 323 mils (polar plot range).

(2) *Battery A.*

Altitude of Battery B ----- 500 meters.
 Vertical interval (with respect to Battery B). -48 meters.
 Altitude of Battery A ----- 452 meters.
 Altitude of registration point 500 meters.
 Vertical interval ----- +48 meters.
 Range corresponding to adjusted quadrant elevation, 337 mils. 6,620 meters.
 First apparent site (+48/6620, GST). +8 mils.
 First apparent adjusted elevation (337-(+8)). 329 mils.
 Range corresponding to first apparent adjusted elevation, 329 mils. 6,500 meters.
 Second apparent site (+48/6500, GST). +8 mils.
 This site agrees with the last site computed; therefore, it is used to determine the adjusted elevation (337-(+8)). 329 mils.

Range corresponding to adjusted elevation, 329 mils (polar plot range). 6,500 meters.

(3) *Battery C.*

Altitude of Battery B ----- 500 meters.
 Vertical interval (with respect to Battery B). +34 meters.
 Altitude of Battery C ----- 534 meters.
 Altitude of registration point 500 meters.
 Vertical interval ----- -34 meters.
 Range corresponding to adjusted quadrant elevation, 320 mils. 6,370 meters.
 First apparent site (-34/6370, GST). -6 mils.
 First apparent adjusted elevation (320 - (-6)). 326 mils.
 Range corresponding to first apparent adjusted elevation, 326 mils. 6,460 meters.
 Second apparent site (-34/6460, GST). -6 mils.
 This site agrees with the last site computed. Therefore, the adjusted elevation is 326 mils. Range corresponding to adjusted elevation, 326 mils (polar plot range). 6,460 meters.

26-14. Determination of Range and Altitude, Time Plot

a. The range and altitude for each battery may be determined as prescribed in paragraph 26-6.

b. Each battery may fire an executive's high burst to determine the site to the registration point (para 26-8). Range, altitude, and adjusted elevation are determined as prescribed in paragraph 26-7.

c. If the relative altitudes of the batteries are known, one battery may fire an executive's high burst to determine its site and altitude with respect to the registration point. The altitudes of the other batteries with respect to the registration point may then be computed. Site is computed by using the vertical interval between the battery and the registration point and the range corresponding to the adjusted time. The adjusted elevation is derived by subtracting the site from the adjusted quadrant elevation.

★*Example:* The batteries of a 155-mm howitzer M109 battalion have registered on a common registration point with charge 5. The relative vertical intervals of the batteries are as follows: A, +9 meters; B, 0 meters; C, -6 meters. Assumed altitude of the registration point is 400 meters. Adjusted data are as follows:

Battery	Adjusted QE	Adjusted time
A -----	330	20.8
B -----	323	20.5
C -----	320	20.0

After conducting its registration, Battery B fired an executive's high burst and determined the site to the registration point to be +9 mils and the vertical interval to be +50 meters.

Battery	Range	Altitude (meters)	Site (mils)	Adjusted elevation (mils)
A ----	6240	359	+7	323
B ----	6160	350	+9	314
C ----	6040	344	+10	310

d. If the site for one battery can be determined by an executive's high burst, a common GFT setting can be constructed and used to determine the sites for the other batteries of the same caliber.

Example: The batteries of a 155-mm howitzer M109 battalion have registered on a common registration point with charge 5. The assumed altitude of the registration point is 400 meters. The adjusted data included the following:

Battery	Adjusted time	Adjusted QE
A -----	21.0	327
B -----	21.7	330
C -----	22.2	339

The site for Battery B, determined from an executive's high burst, is -5 mils. Construct a common GFT setting and determine the polar plot range and altitude as follows:

(1) *Battery B.*

Adjusted quadrant elevation 330 mils.
Site (executive's high burst) -5 mils.
Adjusted elevation (330 - 335 mils.
(-5)).

Range corresponding to adjusted time, 21.7 (polar plot range). 6,460 meters.

Vertical interval (-5×6460 -29 meters. GST).

Note. Since a common GFT setting is to be used to derive site for the other batteries and the vertical intervals for these batteries will be based upon this site, the vertical interval for the battery that fires the executive's high burst is also computed, using the site, not the angle of site.

Altitude of registration point 400 meters.

Altitude of Battery B 429 meters.

The common GFT setting constructed from this data is
GFT B: Charge 5, lot _____,
range 6460, elevation 335,
time 21.7.

(2) *Battery A.* To derive the site for Battery A, move the time gageline to the adjusted time, read the elevation under the elevation gageline of the common GFT setting, and subtract this elevation from the adjusted QE.

Adjusted time ----- 21.0
Adjusted elevation (elevation 323 mils.
gageline).
Adjusted quadrant elevation -- 327 mils.
Site (327-323) ----- +4 mils.
Range corresponding to adjusted time 21.0 (polar plot range). 6,290 meters.
Vertical interval ($+4 \times 6,290$, +22 meters. GST).
Altitude of registration point -- 400 meters.
Altitude of Battery A ----- 378 meters.

(3) *Battery C.*

Adjusted time ----- 22.2
Adjusted elevation (elevation 344 mils.
gageline).
Adjusted quadrant elevation -- 339 mils.
Site (339-344) ----- -5 mils.
Range corresponding to adjusted time 22.2 (polar plot range). 6,570 meters.
Vertical interval (-5×6570 , -29 meters. GST).
Altitude of registration point 400 meters.
Altitude of Battery C ----- 429 meters.

Battery	Range	Altitude (meters)	Site (mils)	Adjusted Elevation (mils)
A	6290	378	+4	323
B	6460	429	-5	335
C	6570	429	-5	344

Section IV. OBSERVED FIRING CHART FOR MORE THAN ONE BATTALION

26-15. General

Massing of fires of more than one battalion by using an observed firing chart is possible provided common control can be established. Common control can be achieved if aiming circles are uniformly declinated. A common registration point with grid coordinates and altitude assigned must be designated for all battalions. Also, one battery of each battalion must be registered on the common registration point. The area in which fires can be accurately massed is smaller than the area represented by the observed firing chart for one battalion. The comparatively large distance between battalions will introduce errors which increase as the distance from the common registration point to the target increases. Relative altitudes of the common registration point and battalion position areas must be known if several wide-spread battalions are to mass their fires effectively.

26-16. Construction of Observed Firing Chart for More Than One Battalion (Plotting Method)

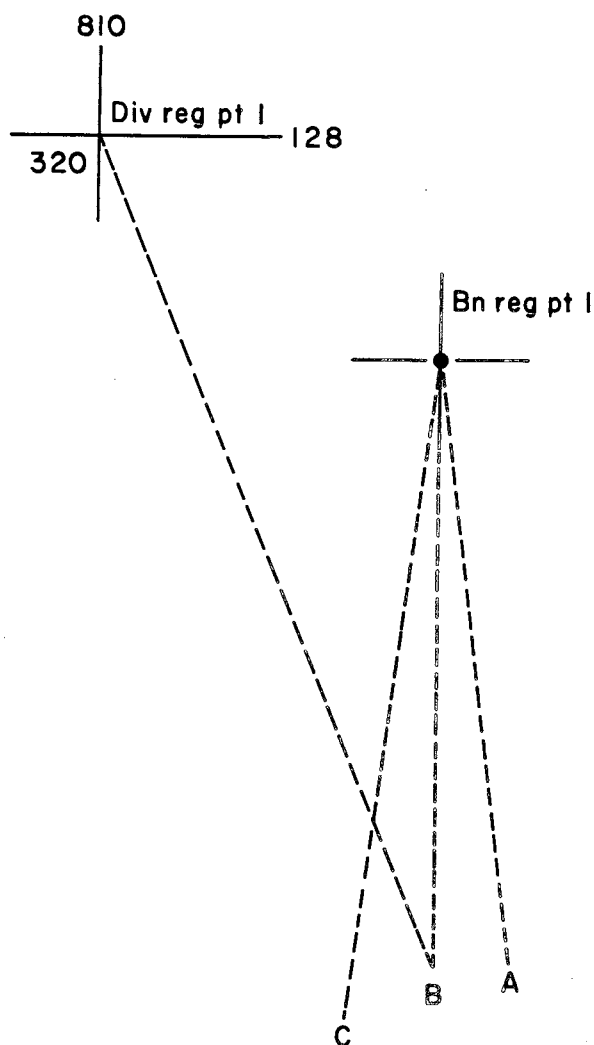
Higher headquarters is responsible for selecting the registration point, assigning arbitrary grid coordinates and altitude, and coordinating registration. Registration may be coordinated by assigning times for conducting registrations or by requiring a single battalion to register one battery of its own and one battery from each of the other battalions involved. Each battalion observed firing chart is constructed as follows (fig. 26-2).

a. The adjusting battery is polar plotted from the common registration point designated by higher headquarters. The back-azimuth of the adjusted azimuth and the distance derived from the adjusted data are used in polar plotting.

b. The battalion registration point is polar plotted from the adjusting battery position. The azimuth and distance (to the battalion registration point) that were determined previously from registration on the battalion registration point are used in polar plotting.

c. Other batteries of the battalion are registered and then polar plotted from the battalion registration point in the normal manner.

d. If the battalion registration point and the common registration point are not within transfer limits or if different charges are used, separate GFT settings and separate deflection correction scales will be established.



★Figure 26-2. Battalion observed firing chart based on registration on a division artillery registration point.

26-17. Construction of Observed Firing Chart for More Than One Battalion (Tracing Paper Method)

An alternate, but less accurate, method of constructing an observed firing chart for more than one battalion is the *tracing paper method*. The chart is constructed as follows:

a. The battalion observed firing chart has been constructed. The battalion registration point, batteries, and fired targets are plotted on the battalion chart. After registration, the common registration point is polar plotted from the adjusting battery on the battalion chart. The altitude of the common registration point is computed.

b. An overlay of the battalion chart is made. The overlay includes all points plotted on the battalion chart.

c. The common registration point is plotted on the chart for more than one battalion at the grid coordinates specified by division artillery or group headquarters.

d. A ray is drawn on the chart for more than one battalion in the direction of the back-azimuth of the adjusted azimuth from the registration on the common registration point.

e. The overlay is then placed over the chart for more than one battalion and is oriented so that the common registration point is placed over its chart location and the registering battery is over the ray previously drawn (d above).

f. The locations of batteries, battalion registration point, and targets are pinpricked through the overlay onto the chart for more than one battalion.

g. All altitudes are reconciled with the altitude assigned to the common registration point.

h. Deflection indexes are constructed on the chart for more than one battalion. The indexes are based on adjusted data for the battalion chart.

Section V. OBSERVED FIRING CHART WITH INCOMPLETE SURVEY

26-18. General

a. A position area survey may sometimes be used in conjunction with the observed firing chart until the surveyed firing chart is available. That part of the chart established by firing must be plotted to the same scale as that part obtained by survey.

b. The following typical situations might necessitate the use of an observed firing chart based on registration of one battery and a position area survey:

(1) When lack of time or ammunition precludes registering all three batteries.

(2) When the battalion displaces by echelon. Data can be ready for the remaining batteries when they arrive at the new position.

(3) When displacement of the battalion is to be made after dark. A single howitzer can be brought up and registered during daylight. Data can be ready for the entire battalion when it arrives.

(4) When alternate positions have been occupied and firing must begin without registration from those positions.

(5) When fire from positions to be occupied is not permitted before a certain hour but massing is required immediately after that time. In such a situation a single registration may be performed from an alternate position. Data can then be prepared for the nonregistering battery positions after they have been connected to the registering battery position with a position area survey.

26-19. Procedure for Construction of Observed Firing Chart, Position Area Survey Only

The procedure for the construction of a battalion observed firing chart based on the registration of one battery and a position area survey is as follows:

a. A common orienting line (OL) is established for the battalion, if possible; otherwise, an orienting line is established for each battery.

b. Starting from any convenient point, a traverse is run to locate all battery positions horizontally and vertically with respect to each

other and to establish common directional control for all orienting lines.

c. The battery positions, altitudes, and orienting lines are plotted on tracing paper to the same scale as that for the chart to be used. This overlay, including the measured grid azimuth of the orienting lines, constitutes the position area survey as delivered to the fire direction center.

d. One battery is registered on the registration point; from the adjusted data, the observed firing chart is started by plotting the registering battery.

e. The azimuth of fire derived from the measured orienting angle of the registering battery is used for the direction of fire line of the

battery on the overlay of the position area survey.

f. The battery center plotted on the overlay is placed over the registering battery center on the firing chart. The overlay is rotated until the direction of fire line on the chart and the overlay coincide. The locations of the nonregistering batteries are pinpricked and then labeled with proper altitudes in relation to the registering battery.

g. The azimuth from each nonregistering battery to the registration point is measured. For each battery, the azimuth of the battery orienting line minus the determined direction of fire equals the orienting angle for laying the battery.

Section VI. RADAR FIRING CHARTS

26-20. General

Three techniques can be used in conjunction with radar-observed high-burst registration in constructing a firing chart. The techniques are as follows:

- a. Observed firing chart improved by radar (time plot).
- b. Radar chart, no maps or survey.
- c. Radar chart, relative location of registering piece and radar determined.

26-21. Time Plot Observed Firing Chart Improved By Radar

In most cases the radar is in position and ready to observe by the time the firing batteries have completed registration. The time plot chart improved by radar may be constructed as soon as the registration of all batteries and a radar-observed high-burst registration by one of the batteries are completed. The radar will supply data for an accurate GFT setting and deflection correction. The time plot observed firing chart improved by radar is the most accurate type of observed firing chart that can be constructed. Construction of a firing chart must not be delayed to await the availability of a radar.

26-22. Advantages of Radar Improved Chart

The radar-improved chart has the following advantages over a time plot observed firing chart:

a. An accurate range and vertical interval can be obtained from the radar location of the high burst. An accurate site can be determined and then subtracted from the quadrant elevation fired to derive an accurate adjusted elevation. When the GFT setting derived from the radar-observed high-burst registration is applied to the adjusted data from a registration on the registration point, polar plot range and altitude can be determined accurately.

b. The direction in which the batteries are polar plotted from the registration point is improved by the amount of the deflection correction determined from the radar-observed high-burst registration.

26-23. Procedure for Construction of Radar-Improved Chart

a. All batteries are registered on a common registration point to determine an adjusted deflection, an adjusted azimuth or orienting angle, an adjusted time, and an adjusted quadrant elevation.

b. The radar is located by survey with respect to one battery, and the locations of the battery and radar are plotted on a firing chart. The battery fires a high-burst registration observed by the radar. The point selected for the high burst should be—

- (1) Visible to the radar.
- (2) As close as possible to the common registration point.
- (3) Low enough that the site is less than 50 mils.

c. The radar section provides the FDC with the azimuth, range, and vertical angle for each round from the radar to the high-burst location.

d. The high-burst location is determined from the radar on the firing chart by the fire direction center.

e. Chart data consisting of range, deflection, and site are then determined from the battery to the high-burst location.

f. The GFT setting is determined. The GFT setting range is the chart range (*e* above). The adjusted elevation is the quadrant elevation used to fire the radar-observed high-burst registration minus the site (*e* above). The adjusted time is the fuze setting used to fire the radar-observed high-burst registration.

g. The deflection correction is computed by subtracting the chart deflection (*e* above) from the deflection used to fire the radar-observed high-burst registration.

h. The common registration point is plotted at assumed grid coordinates on another chart and assigned an assumed altitude. The batteries will be polar plotted from the common registration point.

i. The polar plot direction is determined as follows:

- (1) The direction of fire is determined in the normal manner (para 26-4).
- (2) The deflection correction (*g* above) is subtracted from (1) above.
- (3) The polar plot direction is the back-azimuth of (2) above.

j. The polar plot range is determined by using the GFT setting from the radar-observed high-burst registration. The time gageline is placed over the adjusted time to the registra-

tion point, and the range is read under the hairline.

k. With the time gageline over the adjusted time, the adjusted elevation to the registration point is read under the elevation gageline. The site to the registration point is determined by subtracting the derived adjusted elevation from the adjusted quadrant elevation. The vertical interval and altitude of the battery are computed.

l. The deflection index is constructed at the adjusted deflection.

m. The GFT setting from the radar-observed high-burst registration is used for all firing from the radar-improved charts.

★*Example:* All batteries of a 155-mm howitzer M109 battalion have registered on a common registration point (assumed altitude 400 meters) with charge 5, lot WZ. Adjusted data are shown below:

Battery	Adjusted azimuth	Adjusted deflection	Adjusted QE	Adjusted time
A----	6046	3151	280	18.0
B----	6134	3166	274	17.6
C----	6229	3171	269	17.2

(1) A traverse is run between the radar antenna and the base piece of Battery B. The locations of the radar antenna and Battery B are plotted on a firing chart. The radar is 6 meters above the base piece of Battery B.

(2) Battery B fires a high-burst registration over the registration point with the following data: charge 5, lot WZ, deflection 3166, time 17.6 quadrant 287.

(3) The radar section reports the data to the high-burst location as range 4,360 meters, azimuth 6,074 mils, vertical angle +17 mils. The high-burst location is polar plotted from the radar. The high-burst location is 73 meters above the radar (GST: 4360 X (+17)).

(4) Chart data from Battery B to the high-burst location are measured as deflection 3,181 mils, range 5,320 meters.

(5) The GFT setting is determined as follows:

Height of high burst with respect to radar.	+73 meters.
Height of radar with respect to Battery B.	+6 meters.

Height of high burst with respect to Battery B. +79 meters.
 Chart range, Battery B to high burst. 5,320 meters.
 Site, Battery B to high burst (GST: chg 5; +79/ 5320). +16 mils.
 Adjusted elevation (287-16). 271 mils.
 GFT B: Charge 5, lot WZ, range 5320, elevation 271, time 17.6.

(6) The total deflection correction is determined as follows:

Chart deflection, Battery B to high burst. 3,181 mils.
 Adjusted deflection 3,166 mils.
 Total deflection correction .. R15 mils.

★(7) The polar plot data are computed by using the GFT setting ((5) above), the deflection correction ((6) above), and the adjusted data from the common registration point.

Element	A	Battery B	C
Adjusted azimuth to registration point.	6046	6134	6229
Total deflection correction	R15	R15	R15
Corrected azimuth to registration point.	6031	6119	6214
Polar plot azimuth	2831	2919	3014
Range (corresponding to adjusted time).	5420	5320	5220
Elevation	277	271	264
Adjusted quadrant elevation ..	280	274	269
Site (adj QE-el)	+3	+3	+5
Vertical interval	+15	+15	+24
Altitude	385	385	376
Deflection index constructed at deflection.	3151	3166	3171

26-24. Radar Chart

Without radar, there is no easy and practical method by which a battalion can occupy positions during darkness without maps or prior survey and be prepared to mass effective fires as daylight. However, when radar is available, an observed firing chart can be constructed which will permit the battalion to mass fire effectively. This observed firing chart is called the *radar chart*.

26-25. Construction of Radar Chart

The radar chart is not as accurate as an observed firing chart improved by radar. The construction of the radar chart is based on the

firing of a high-burst registration by each battery. The procedures for construction of the radar chart are as follows:

a. The radar is oriented by using the aiming circle and is plotted on the firing chart at assumed grid coordinates and altitude.

b. The batteries are laid by azimuth on the approximate azimuth to the center of the sector.

c. A high-burst registration, observed by radar, is fired from the base piece of each battery at a safe range and fuze setting.

d. Range, azimuth, and vertical angle to each of the three high bursts are reported to the fire direction center.

e. Each high burst is polar plotted on the firing chart with respect to the radar.

f. The altitude of each high burst is determined by using the radar range and vertical angle.

g. Each battery is back plotted on the chart from its high-burst location.

(1) Each high burst represents the registration point of the battery which fired it.

(2) The battery is polar plotted from its high-burst location on the back-azimuth of the azimuth at which the high burst was fired.

(3) The range at which the battery is plotted is the range corresponding to the fuze setting at which the high burst was fired.

h. The altitude of the battery is equal to the altitude of its high burst minus the vertical interval between the battery and the high burst. The vertical interval is determined by multiplying the derived site by the range at which the battery is plotted (GST).

i. The deflection index is constructed for each battery at the adjusted deflection (deflection fired).

26-26. Evaluation of Radar Chart

The radar chart is fundamentally a time plot observed firing chart, sites unknown, with the exception that each battery has its own registration point. The accuracy of the radar chart is slightly less than that of the time plot observed firing chart, sites unknown.

a. The accuracy of the radar chart can be increased and usable battalion transfer limits

can be obtained if the three high-burst registrations are fired as close as possible to the same point.

b. Without survey, pointing data for the radar to each of the high bursts cannot be determined accurately. For this reason, generally it will be necessary to move the antenna in azimuth and elevation after the first round is fired in order to observe succeeding rounds through the orienting telescope. Therefore, each registration usually will require seven or eight rounds.

c. The radar chart can be used to mass fires on targets reported by radar and on targets which have been adjusted on by one battery.

26-27. Radar Chart, Registering Piece Located

If the relative location of the radar and the registering piece can be established, either by survey or by moving the registering piece to the radar, the accuracy of the radar chart can be substantially improved, since a GFT setting and deflection correction can be established.

a. When one battery position is located in relation to radar after a radar chart without survey or maps has been constructed, a GFT setting and deflection correction can be derived from the registration of that battery. When a registering piece is moved to the radar position, another high-burst registration must be fired to establish a GFT setting and deflection correction.

b. When radar is located relative to one battery prior to initial registration, the high-burst registration of this battery is used to establish the GFT setting and deflection correction.

c. The GFT setting and deflection correction in *a* and *b* above are established and applied in back plotting each battery from its respective high-burst location for a radar chart in the same manner as for an observed firing chart improved by radar. However, the chart thus established is not as accurate as the observed firing chart improved by radar, since the high bursts are not at a common point.

Section VII. TRANSFER FROM OBSERVED FIRING CHART TO SURVEYED FIRING CHART

26-28. General

As soon as the surveyed firing chart is available, it should replace the observed firing chart. The observed firing chart is retained until all targets are transferred to the surveyed firing chart. The transfer of information is made as soon as possible.

26-29. GFT Settings and Deflection Index

a. The procedure for determination of GFT settings and construction of the deflection indexes for use with the surveyed firing chart is the same as that followed when the surveyed firing chart is available at the time the registration is fired. The adjusted elevation is determined by subtracting the site, as computed from the surveyed firing chart, from the adjusted quadrant elevation. The range is measured on the surveyed firing chart. The time gage line is drawn over the adjusted time for each registration. When all three batteries

have registered on the observed firing chart, each may have a different GFT setting.

b. The deflection index is constructed at the referred deflections. The deflection correction scale to be used with the surveyed firing chart is based on the survey chart GFT setting with the deflection correction indicated at registration point range.

26-30. Transfer From Observed Firing Chart to Surveyed Firing Chart, Percussion Fuze

a. The procedure for transfer of targets from the observed firing chart to the surveyed firing chart is the same as that for replotting observed targets on the surveyed firing chart (para 20-16). Data for replot of a target are obtained from the adjusted data for that target. (Determination of adjusted data and replot data is discussed in para 26-32.)

(1) The target is plotted on the surveyed

firing chart by using the FFE deflection from the observed firing chart minus the deflection correction at the FFE elevation. The deflection correction is obtained from the surveyed chart deflection correction scale.

(2) If a map is not available, any information indicating the altitude of the target, such as the observer's up or down correction, is used to determine the vertical interval. Successive approximation is required in order to determine site and the adjusted elevation (para 26-13b).

(3) The surveyed firing chart GFT setting is used to derive the range from the adjusted elevation.

b. When more than one registration has been made, the elevation used in establishing the GFT setting is selected from the registration which most nearly coincides with the time of firing on the targets.

26-31. Transfer From Observed Firing Chart To Surveyed Firing Chart, Time Fuze

Targets fired with time fuze are transferred from the observed firing chart to the surveyed firing chart in the same manner as targets fired with percussion fuze, except for the following:

a. The relationship between range, adjusted time, and adjusted elevation is fixed by the surveyed firing chart GFT setting.

b. The time gageline is placed over the adjusted time. Range is read under the hairline, and the adjusted elevation is read under the elevation gageline.

c. The adjusted elevation is subtracted from the quadrant elevation (minus 20/R at fire-for-effect range) to determine the site. This site and the range determined in *b* above are used to obtain the vertical interval.

26-32. Transfer to Surveyed Firing Chart, Computer Records Available

When the computer's records are available, targets are replotted on the surveyed firing chart by polar plotting at deflections, ranges, and altitudes as described below.

a. *Deflection.* The deflection used to replot the target on the surveyed firing chart is obtained in the manner prescribed in paragraph 26-30a(1).

b. *Range.* Range is determined with the GFT setting for the surveyed firing chart. For missions fired with percussion fuze, range is determined by placing the elevation gageline over the adjusted elevation and reading the range under the hairline. For missions fired with time fuze, range is determined by placing the time gageline over the adjusted time setting and reading the range under the hairline.

c. *Site and Elevation (Percussion Fuze).*

(1) The altitude of the target is determined from a map or from the observer's call for fire. For example, the observer requested FROM REGISTRATION POINT 1, RIGHT 350, ADD 400, UP 20. The target is 20 meters above the registration point.

(2) The site is determined by successive approximation. Site is based on the vertical interval (difference in the altitude of the battery and target) and fire-for-effect range.

(3) The final adjusted elevation is used to determine the final plot range.

d. *Site and Elevation (Time Fuze).* The adjusted elevation must be obtained for each target. The adjusted elevation is obtained by placing the surveyed GFT setting time gageline over the adjusted time and reading the elevation under the gageline. The site is derived by subtracting the elevation from the adjusted quadrant elevation (minus 20/R at fire-for-effect range).

★e. *Example of Target Replotted on a Surveyed Firing Chart.* Personnel of a 155-mm howitzer battalion have completed survey and are transferring from an observed firing chart (percussion fuze) to a surveyed firing chart. Surveyed firing chart GFT setting is GFT B. Charge 5, lot XT, range 6070, elevation 310. Target AF 2401 is to be replotted on the surveyed firing chart. No map is available.

Fuze	Data from computer's record			Observer's vertical correction
	Deflection	Range	QE	
Q	3216	6400	354	From Reg Pt 1, UP 70

Total deflection correction from deflection correction scale. L7

Altitude of battery 420 meters
 Altitude of registration point (survey) 438 meters
 Altitude of target (438 + 70) 508 meters
 Vertical interval +88 meters
 Apparent site of target (GST) (88/6400). +15 mils
 Quadrant elevation fired 354 mils

Apparent adjusted elevation (354 - 339 mils
 (+15)).
 Apparent range for replot (GFT) 6,490 meters
 Site (GST) (88/6490) +15 mils*
 Replot range 6,490 meters
 Replot deflection (3216 - L7) 3,209 mils

*Agrees with first apparent site.

PART FIVE

MISCELLANEOUS

CHAPTER 27

TARGET ANALYSIS AND ATTACK

27-1. General

The commander or his designated gunnery officer must consider certain factors when deciding to attack a target or when planning fires. Conformity to the scheme of maneuver of the supported unit and evaluation of the enemy are factors of primary concern. For detailed information concerning field artillery tactics, see FM 6-20-1 and FM 6-20-2. For detailed information concerning nonnuclear lethality and effects, see FM 6-141-1 and FM 6-141-2.

27-2. Description of Target

The method of attacking a target depends largely on the description of the target. The description of the target includes type, size, density, cover, mobility, and importance. To determine the proper type of projectile, fuze, caliber of weapon, and necessary ammunition expenditure, the observer and the S3 must consider carefully the description of the target. The description of the target is also a guiding factor in determining the type of adjustment and the speed of attack.

a. Fortified targets or armor must be destroyed by precision fire, assault fire, or direct fire using projectiles and fuzes appropriate for penetration. The highest practicable charge should be used in assault and direct fire to increase penetration and to decrease vertical dispersion. The charge with the smallest *PE*_r should be used in precision fire to decrease horizontal dispersion. If the target is flammable, projectile WP should be mixed with projectile HE—WP to ignite materiel and HE to cause fragmentation damage.

b. A target consisting of both personnel and materiel normally is attacked by area fire, using air or impact bursts to neutralize the area. The selection of caliber, projectile, and fuze is influenced by the extent of damage desired.

c. Since the precision with which the observer (or other target acquisition agency) can determine

the dimensions of the target is limited and because area targets are seldom precisely delineated, it is convenient to adopt standard terms for target reporting.

- (1) *Target depth.* All area targets are assumed to be approximately 250 meters in depth; 250 meters is the depth of battery three rounds from a 105-mm howitzer battery and is approximately the depth of battery one round from a 155-mm howitzer battery. Targets greater than 300 meters in depth may be attacked as two targets. No special corrections are required to achieve a standard depth.
- (2) *Scales.* Three scale designations for targets have been selected.
 - (a) *Scale 0.* Scale 0 designates those targets ranging from a virtual point to approximately 100 meters in width. Scale 0 targets can be assumed to be 75 meters wide. It is assumed that a parallel or open sheaf of any caliber will more than cover a scale 0 target. If the mean point of impact is adjusted on a scale 0 target, ammunition will be wasted during fire for effect with a situation in which it cannot be predicted that the mean point of impact will fall on the center of the target (e.g., unobserved fires) may dictate the use of a parallel or open sheaf with a scale 0 target. If an observer is adjusting on a scale 0 target, normally he will converge the sheaf.
 - (b) *Scale 1.* Scale 1 targets are targets that are wider than scale 0 and up to 300 meters in width; that is, scale 1 targets are assumed to be 250 meters in width. This figure has been chosen because it bears a convenient relationship to the effective front covered by the

parallel sheaf of a 105-mm, a 155-mm, or an 8-inch howitzer battery.

- (c) *Scale 2.* Scale 2 targets are targets assumed to be greater than 300 meters and up to 450 meters in width; that is, scale 2 targets are assumed to be 350 meters in width. This figure has been chosen because it represents the effective front covered by the 105-mm, 155-mm, or 8-inch howitzer battalion firing one round, parallel sheaf, at the target center.

- (3) *Standard target sizes.* Standard target sizes of any dimensions may be adopted to satisfy conditions encountered. The dimensions of a target are needed for computations to determine the type and volume of fire to achieve desired results. A few fixed sizes meet the requirement.

27-3. Results Desired

The method of attacking a target is influenced by the results desired. Results are of four types—destruction, neutralization, harassing, and interdiction. The methods of attacking targets to achieve the desired results are as follows:

a. Destruction fire—Fire delivered for the sole purpose of destroying material objects.

b. Neutralization fire—Fire delivered for the purpose of reducing the combat efficiency of the enemy by hampering and interrupting the fire of his weapons, by reducing his freedom of action, by reducing his ability to inflict casualties on our troops, and by severely reducing his movement within an area. Most artillery fire missions seek to neutralize the target. Neutralization is often maintained by following the initial fires with repeated fires of less intensity at varying intervals.

c. Harassing fire—Fire delivered for purposes of disturbing the rest, curtailing the movement, and lowering the morale of enemy troops by the threat of casualties or losses in materiel.

d. Interdiction fire—Fire delivered for the purpose of denying the enemy the unrestricted use of an area or point. Interdiction fire is usually of less intensity than neutralization fire.

27-4. Registration and Survey Control

a. Effective transfers are accomplished best when data from survey and current registrations are available or when current met messages and

muzzle velocity data are available. When survey, registration, and met data are not available or are inadequate, targets should be attacked with observed fires since, in such cases, unobserved fires may be ineffective.

b. To the extent possible, surveillance should be obtained on all missions, to determine the results of fire for effect. Accurate fire for effect without adjustment is highly effective against targets which contain personnel or mobile equipment. All destruction missions and missions fired at moving targets must be observed and fire for effect adjusted to the target.

27-5. Area To Be Attacked

a. The size of the area to be attacked may be determined by the actual size of the target or by the area in which the target is known or suspected to be. This information is usually an estimation and is obtained from observers' reports, photographic interpretation, intelligence agencies, and experience in similar situations. The size of the area to be attacked is an important factor to be considered in the selection of units to fire (para 27-8b).

b. Normally, a battalion should not fire with a range spread greater than 1 C (100 meters), since a greater spread will not give uniform coverage of the target. When choosing the range spread to be used, the S3 should consider the probable error, lethality, and effect desired.

27-6. Maximum Rate of Fire

a. The greatest effect is achieved when surprise fire is delivered with maximum intensity. Intensity is best secured by massing the fires of several batteries or battalions using time-on-target (TOT) procedures. The intensity of fires available by firing many rounds from a few units is limited by the maximum rate of fire (*b* below).

b. The maximum rates of fire shown in table 1-1 are guides. These rates cannot be exceeded without danger of damaging the tube. To maintain these rates (either to maintain neutralization on one target or to attack a series of targets), it is important that the pieces be rested or cooled from previous firing. The lowest charge possible should be used during periods of prolonged firing, since heating is more pronounced with the higher charges.

27-7. Amount and Type of Ammunition

a. The amount of ammunition available is an important consideration in the attack of targets. The available supply rate will not be exceeded except by authority of higher headquarters. When the available supply rate is low, missions should be limited to those which contribute the most to the mission of supported units. When the available supply rate is high, missions fired may include missions which may affect planned or future operations and some missions which require massing of fires without adjustment.

b. The selection of a charge with which to attack a target depends on the range, terrain, and type of ammunition. The maximum range of the charge selected for an adjustment should be at least one-third greater than the range to the target when data are obtained by approximate methods and one-eighth greater than the range to the target when data are obtained by precise methods to insure that the target can be reached. If possible, a charge giving an elevation to the target of between 240 and 460 mils should be selected for howitzers. For flat-trajectory weapons, there is a greater overlap in charges and no specific rule can be applied.

c. The type of ammunition selected to attack a target depends on the nature of the target and the characteristics of the ammunition available for the cannon to be used.

d. The effect of HE ammunition varies with the fuze employed.

- (1) Since the effective fragmentation of an impact HE projectile is greatest if it

lands on hard ground at a large angle of impact, the lowest charge that can be used without excessive dispersion will give the greatest effective fragmentation (fig. 27-1). When the projectile passes through trees, the detonation may occur in the foliage and effectiveness may be either improved or lost, depending on the density of the foliage and the nature of the target.

- (2) The three types of fuzes that are used with HE ammunition to obtain airbursts are proximity (VT), time, and delay fired to ricochet. The three types are listed below in order of effectiveness.

- (a) *Fuze VT.* Fuze VT detonates automatically upon approach to a reflective object. Fuze VT is used to obtain airbursts (fig. 27-2) without the necessity of adjusting height of burst. If the VT element fails to function, fuze quick action occurs upon impact. The height of burst of fuze VT varies with the slope of fall and with the terrain in the target area. If the terrain surrounding the target area is wet or marshy, the height of burst will be increased. Light foliage has little effect on VT fuze, but heavy foliage will increase the height of burst by about the height of the foliage. Since it is not limited by range and because the height of burst probable error is smaller, VT fuze is

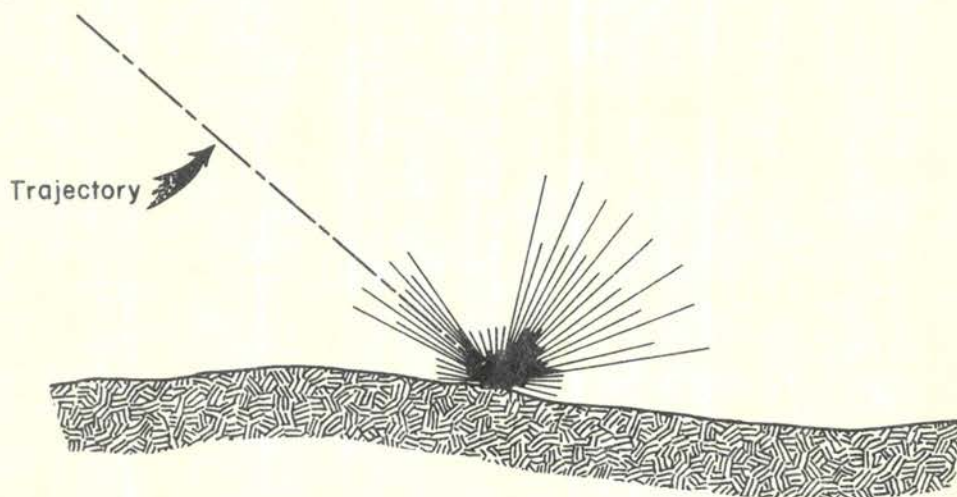


Figure 27-1. Effect of impact burst with fuze quick.

preferred to time fuze for targets which are at long ranges, which require high-angle fire, or which must be attacked at night. The greater the angle of fall, the closer the burst will be to the ground. When the target is close to friendly troops, the lowest practicable charge should be used to obtain a large angle of fall.

- (b) *Fuze time.* Airbursts may be obtained by the use of fuze time (fig. 27-2). The height of burst is determined by the quadrant elevation, charge, and fuze setting. If the time element fails to function with fuze time, fuze quick action occurs upon impact. When fuze time is used, the height of burst can be adjusted, but, because of dispersion, not all bursts will be at the desired height. The highest practicable charge should be used with fuze time to minimize the height of burst probable error. A height of burst probable error greater than 15 meters is considered excessive.
- (c) *Fuze delay.* Fuze delay may be used to obtain airbursts by ricochet. If the angle of impact is small and the surface the projectile strikes is firm, the projectile will ricochet before detonating

and produce airbursts (fig. 27-3). Because of the uncertainty of ricochet actions, fuze delay to obtain ricochets should not be fired without observation. The highest practicable charge should be used to obtain ricochet bursts with fuze delay. If the angle of impact is too great, the projectile will penetrate before detonating, producing mine action (fig. 27-4). Fuze delay can be used to destroy earth and log fortifications and is effective against some masonry and concrete. Fuze delay should not be used against heavy armor.

- (3) Greater penetration against masonry or concrete can be obtained with HE ammunition by using a concrete-piercing fuze. There are two types of concrete-piercing fuzes: nondelay, used primarily for clearing rubble, and delay, used for greater penetration. High-explosive anti-tank (HEAT) ammunition can be used against reinforced concrete or heavy masonry. The HE projectile with fuze delay is used at intervals to clear away rubble and blow apart shattered fragments. The effectiveness of various caliber weapons against concrete is shown in table 27-1.

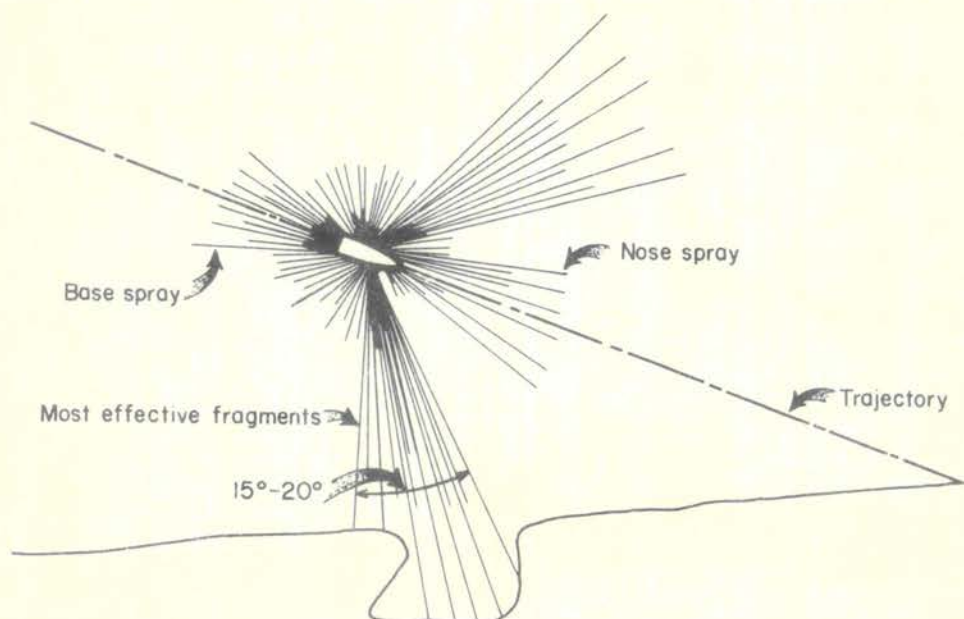


Figure 27-2. Effect of airburst with VT or time fuze.

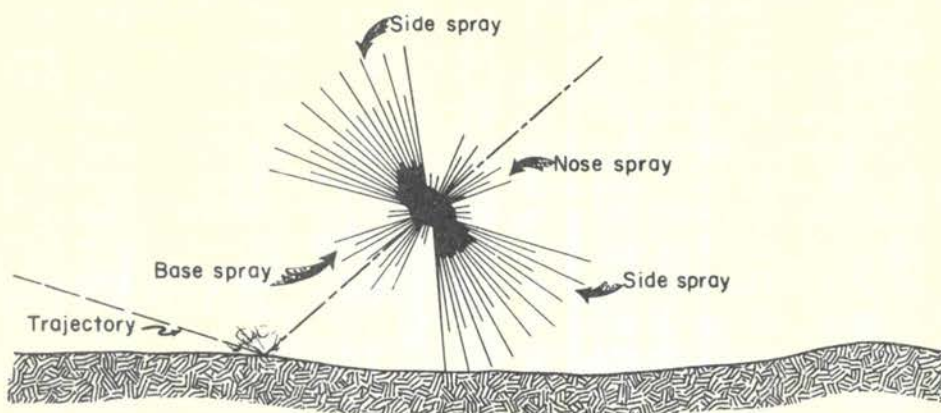


Figure 27-3. Effect of airburst with fuze delay (ricochet).

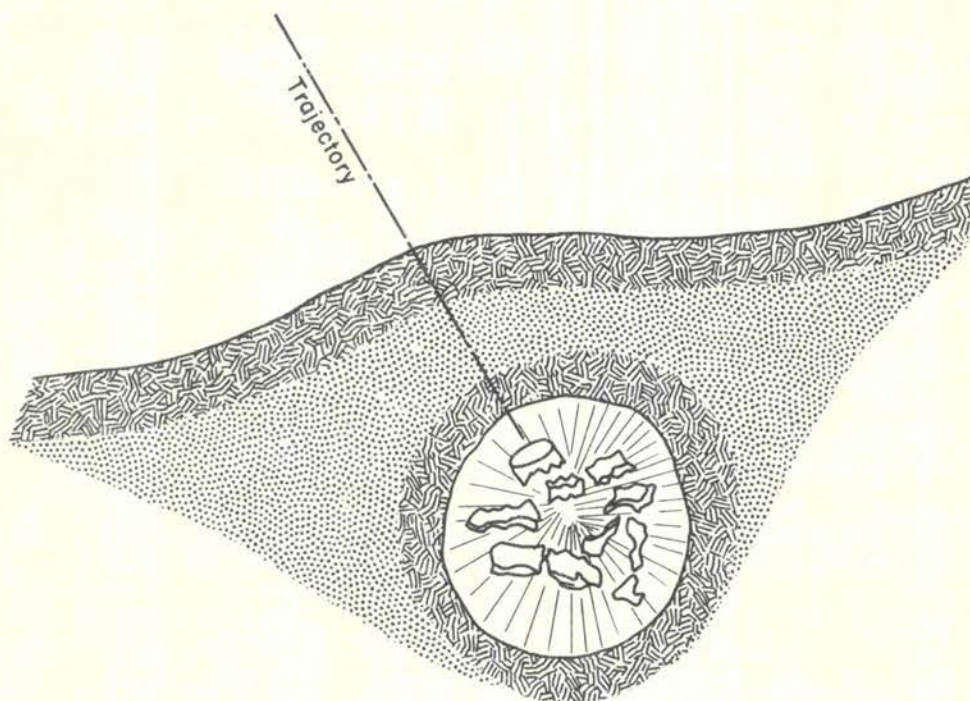


Figure 27-4. Mine action, fuze delay.

e. High-explosive antitank projectiles are designed for attacking armor targets.

- (1) High-explosive antitank (HEAT) projectiles are available for 105-mm howitzers. The HEAT projectile contains a

shaped charge and is propelled by a fixed charge.

- (2) HEAT ammunition is relatively ineffective against personnel in the open because of the small amount of fragmentation.

Bursts are difficult to observe. HEAT ammunition is more effective at short ranges and normally is fired during direct laying. Adjustment of indirect fire, when necessary, is conducted with HE ammunition until fire for effect is commenced.

- (3) The 155-mm howitzer and larger weapons using HE ammunition with fuze quick are effective against armor in the direct fire role because of the size and explosive power of the projectile.

f. Chemical ammunition is used for producing casualties, for incendiary, for screening, and for marking. Among the types of fillings in chemical projectiles are toxic agents, white phosphorus, smoke HC, and colored smoke.

- (1) Projectiles filled with toxic agents are particularly useful for causing casualties in fortified positions or installations. See FM 3-10 for detailed information on the use of chemical projectiles. Toxic chemicals may be used at low expenditure rates to harass the enemy and require them to wear protective masks for prolonged periods.
- (2) The influence of weather (direction and speed of wind, temperature, and temperature gradient) has a great deal to do with the effectiveness and tactical desirability of chemical agents. If favorable weather conditions exist, toxic agents will be more effective than HE on a round for round basis in some situations.

Table 27-1. *Effect on Concrete*

Cannon and projectile (maximum charge)	Thickness* of concrete perforated by single round (face perpendicular to line of impact) (cm)			Thick- ness (meters)	Number of rounds falling in circle of given diameter** necessary to perforate various thicknesses* of concrete at given ranges			
	Range (meters)				Range (meters)			
	900	2,700	3,600		900	2,700	3,600	
105-mm howitzer; HE M1, fuze M78 series-----	64	48	46	{	0.9	5	10	12
				{	1.5	14	27	33
				{	2.1	27	53	64
155-mm howitzer; HE M107, fuze M78 series-----	119	98	82	{	0.9	1	1	2
				{	1.5	3	5	9
				{	2.1	7	11	18
8-inch howitzer; HE M106 fuze M78 series-----	168	143	122	{	0.9	1	1	1
				{	1.5	1	2	4
				{	2.1	3	5	8

*Thickness perforated is based on a line of impact perpendicular to the surface. The effectiveness decreases rapidly when the line of impact is other than perpendicular to the surface. Ricochets will occur when the line of impact is 20° to 35° or more from the perpendicular. The higher the striking velocity, the greater the angle may be before ricochet occurs. After the surface

has been chipped, the angle may be still greater.

**Diameter of circles used as a basis for data.

105-mm howitzer-----	0.9 meter.
155-mm howitzer-----	1.2 meters.
8-inch howitzer-----	1.5 meters.

27-8. Considerations in Selection of Units to Fire

a. The unit selected for a mission must have cannons of the proper size and caliber to cover the target area quickly, effectively, and economically. Many targets are of such size as to allow a wide choice in the selection of the number of batteries or battalions to be used. If the unit selected to fire cannot mass its fire in an area as small as the target area, ammunition will be wasted. Conversely, if a unit can cover only a small part of the target area at a time, surprise is lost during the shifting

of fire and the rate of fire for the area as a whole may be insufficient to secure the desired effect. The decision of whether to have many units firing a few rounds on a large target or a few units firing many rounds is often a critical one (b below).

b. Many overlapping factors affect the selection of units and the number of rounds to fire on a target. Some of these factors are discussed in (1) through (10) below.

- (1) *Availability of artillery.* When the number of available artillery fire units is small, more targets must be assigned to each artillery unit.

- (2) *Size of the area to be covered.* The size of the area to be covered must be compared to the effective depth and width of sheaf to be used by the battery or batteries available.
- (3) *Increased area coverage.* Targets greater in depth and width than the standard sizes discussed in paragraph 27-2c can be covered by—
 - (a) Increasing the number of batteries firing.
 - (b) Dividing the target into several targets and assigning portions to different batteries.
 - (c) Shifting fire laterally or using zone fire with a single battery or with a number of batteries controlled as a single fire unit.
- (4) *Caliber and type of unit.* The projectiles of larger calibers are more effective for destruction missions. High-velocity guns are desired for maximum penetration of fortifications.
- (5) *Surprise.* For surprise, a few rounds from many pieces are preferred to many rounds from a few pieces.
- (6) *Accuracy of target location.* Certain important targets which are not accurately located may justify the fire of several units to insure coverage.
- (7) *Critical targets.* The emergency nature of certain targets may justify the use of all available artillery fire. Enemy counter-attack formations are such targets.
- (8) *Dispersion.* At extreme ranges for a given cannon and charge, fire is less dense. More ammunition is required to effectively cover the target. The selection of a unit to fire along the long axis of the target in order to obtain the maximum effect from dispersion may be required when the target is at an extreme range. At normal elevations probable error and dispersion do not present a serious problem.
- (9) *Maintenance of neutralization and interdiction.* Neutralization and interdiction fires may be maintained by the use of a few small units rather than all units which fired for effect. A unit may be able to fire other missions during the same period that it is maintaining neutralization or interdiction fires.
- (10) *Vulnerability of targets.* Some targets should be attacked rapidly with massed fire while they are vulnerable. Examples of such targets are truck parks or personnel in the open.

27-9. Technique of Attack

The technique of attack is determined by an analysis of the capabilities of the cannons and ammunition available and the terrain of the target area. High-angle fire may be needed to fire into or out of defiladed positions.

27-10. Typical Targets and Method of Attack

a. Enemy materiel and fortifications and personnel in sufficient numbers to justify ammunition expenditure are generally artillery targets. However, artillery is not effective against minefields and barbed wire.

- (1) *Minefields.* HE ammunition is ineffective for clearing minefields. The mines are detonated only by direct hits. Artillery fire fails to clear the minefields and only creates more of a problem in locating and removing the mines by hand and in moving equipment across the mined area.
- (2) *Barbed wire.* The employment of artillery to breach wire requires extravagant use of ammunition.

b. Typical targets and suggested methods of attack are listed in table 27-2.

Table 27-2. *Typical Targets and Suggested Methods of Attack*

(Located in back of manual)

CHAPTER 28

SERVICE PRACTICE

Section I. SERVICE PRACTICE PROCEDURES

28-1. General

a. Service practice is a practical exercise in which all elements of the gunnery team are trained in the use of service ammunition. Each service practice should begin with a tactical situation given by the officer in charge of firing. The primary purpose of service practice is to train artillerymen to adjust artillery fire. Fire direction personnel and the firing battery are also trained in their duties during service practice. Prescribed gunnery procedures and techniques should be used, except when judgment clearly indicates that a departure from normal procedure will expedite the mission.

b. Service practice is part of the tactical field training of field artillery units. All elements of training, to include mobility, communication, tactical employment, and conduct of fire, should be combined in the service practice.

c. A service practice is an instructional medium and should be conducted with the same briskness and precision as any military drill. The officer in charge of firing must make full use of the service practice and allow no lulls in the exercise. Observers must conduct each mission in a brisk, businesslike manner.

d. This chapter will serve as a guide in training personnel in observer procedures for the conduct of fire.

28-2. Roles of Key Personnel

a. *Installation Commander.* The commanding officer of an installation is responsible for the maintenance and the assignment of the firing ranges allotted to his command. He must insure that the safety precautions prescribed in AR 385-63 are followed. A range officer assists the commanding officer in all matters pertaining to firing ranges.

b. *Range Officer.* The range officer is responsible to the commanding officer for the preparation and maintenance of the firing ranges. Among his responsibilities are the preparation, authentication, and distribution of safety cards. The safety card is prepared in accordance with AR 385-63.

c. *Officer in Charge of Firing.* The officer in charge of firing is responsible for all aspects of a training exercise that involves firing live ammunition. He is responsible for safety. Normally, he has safety officers to assist him.

d. *Safety Officer.* The safety officer at the firing point represents the officer in charge of firing. Orders issued by the safety officer that prohibit firing can be rescinded only by the officer in charge of firing. The safety officer should interfere as little as possible with the delivery of fire. The safety officer will not be detailed to check or correct errors in laying or servicing the pieces that do not affect safety or will not be assigned any additional duties during firing.

28-3. Training Prior to Service Practice

a. The gunnery techniques and procedures involved in a service practice must be taught before the unit conducts service practice.

b. The service practice OP is not the place to learn conduct of fire procedure. All procedures should be learned before going to the observation post. Familiarity with procedures can be attained by firing simulated missions. A simple and effective method for practicing simulated missions is the "matchbox problem." Matchbox problems require no equipment except a small object, such as a matchbox, and a piece of paper on which a mil scale has been drawn to represent the scale of the reticle in the binoculars. Two or more persons should work together on these problems. The matchbox, which represents the target, is placed on a table or on any convenient surface and the mil scale is placed on the table in front of the target (fig. 28-1). The person acting as the observer faces the target and mil scale and announces the call for fire and the OT distance to the second person, who stands beside the table and announces the message to observer and SHOT. After announcing SHOT, the person at the table places the top of a pencil on the table for a moment to simulate each burst. The observer determines the lo-

cation of the burst(s) as over or short and the amount of deviation in mils in relation to the paper mil scale as seen from his position; e.g., SHORT, 20 RIGHT. The spotting is followed immediately by the observer's correction; e.g., LEFT 40, ADD 400. This procedure is continued until the mission is completed. The person at the table critiques the mission and changes places with the person acting as the observer.

28-4. Preparation for Service Practice

Well in advance of the scheduled service practice, the officer in charge should—

a. Make a ground reconnaissance of the area and select the observation post to give the desired angle of observation.

b. Prepare a map and plot the locations of the batteries, observation post, safety limits, and registration points.

c. Select appropriate reference points and targets.

d. Obtain the safety card from the range officer. The officer in charge of firing must check the safety cards and, if they are not correct, he must reconcile the differences with the range officer. One copy of the approved safety card is delivered to the safety officer(s) prior to the service practice, and one copy is retained by the officer in charge of firing.

28-5. Procedures at the Observation Post

a. The officer in charge of firing must arrive at the OP sufficiently in advance of the participating personnel to insure that the observation post is properly organized so that all observers will have a good view of the target area. Figure 28-2 depicts a typical nontactical observation post arrangement. Preparation must include a thorough

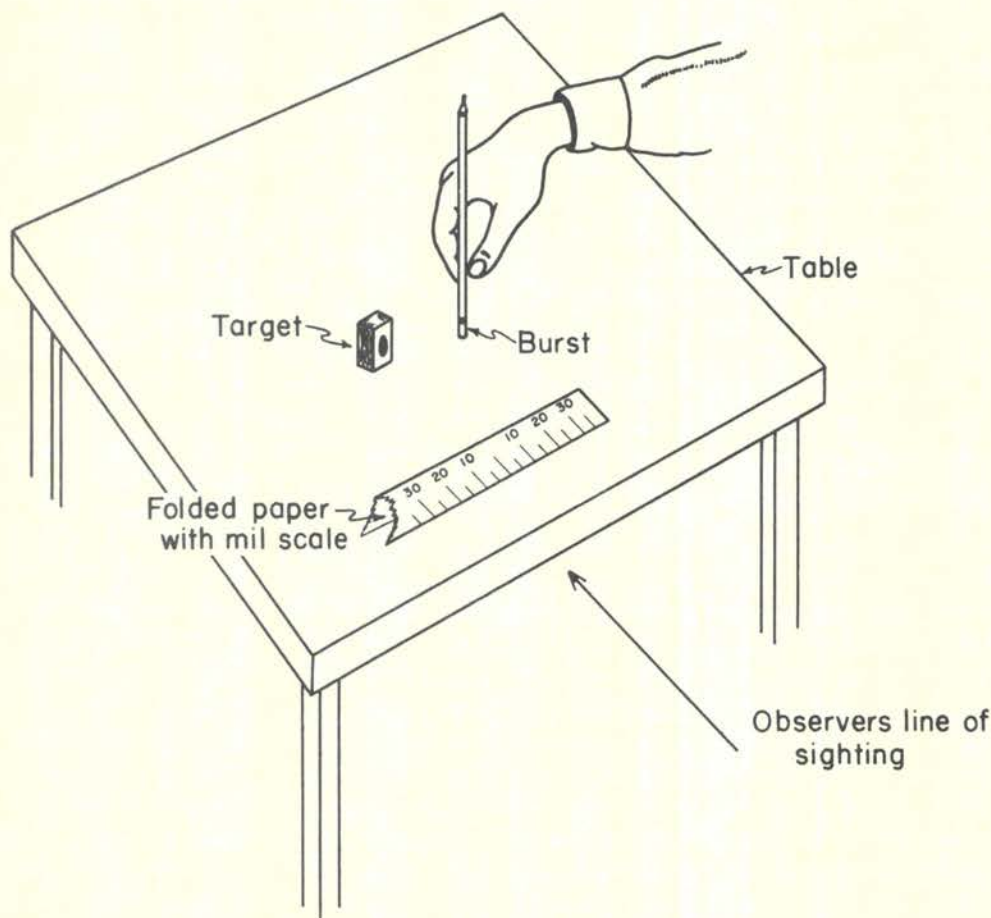


Figure 28-1. Matchbox problem setup

check of communications and a check with range control to insure that the range is clear and it is safe to fire.

b. An orientation on the terrain must be given to all observer personnel and should include the limits of the target area. A good method is to describe a tactical situation involving the location of friendly troops, zones of action, and final objective. For subsequent target designation, the orientation should define reference points and the direction to one or more of the points. If possible, these points should be on the horizon and not more than 200 mils apart.

c. The observers should be given pertinent parts of the battery executive's report and any information available at the fire direction center which will assist them in calling for fire. Types of fuzes and projectiles available should not be given at this time. The observer should be told to consider all types of fuzes and projectiles authorized in the basic load in selecting the ammunition for his mission.

28-6. Designation of Targets

a. Targets should be designated in a uniform manner. This enables the personnel to become accustomed to a routine and to devote their efforts to making precise measurements. Targets should be designated by announcing the size, nature, and location relative to the nearest reference point and the skyline. The targets should be realistically described in a sound tactical location; e.g., observation post on a point that affords observation or mortars in defilade.

b. Target locations should be exact (deviations should be checked with a battery commander's telescope). Immediately before he designates a target, the officer in charge should verify his description of the target by observing the target through his fieldglasses.

c. The descriptions of targets must be varied to cause observers to consider selection of the proper fuze and projectile. The description should depict a realistic target. The following are examples of proper designations of targets:

- (1) TO IDENTIFY TWO MORTARS FIRING, FROM THE LONE TREE GO LEFT 85 MILS, DOWN FROM SKYLINE AT THAT POINT 15 MILS. THIS WILL PLACE YOU

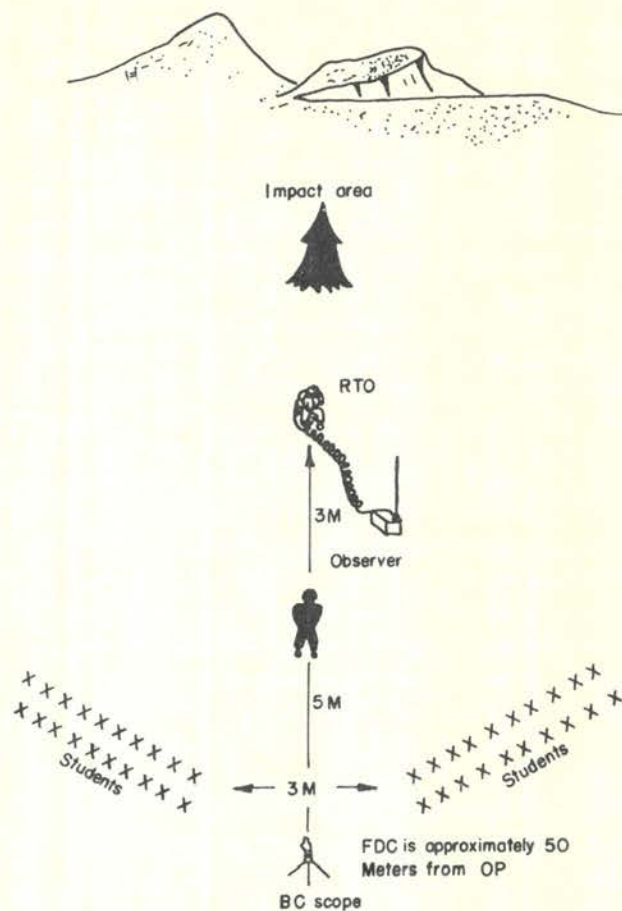


Figure 28-2. Typical nontactical observation post arrangement

ON YELLOW MATERIEL. THAT IS THE ADJUSTING POINT.

- (2) TO IDENTIFY A CAVE ENTRANCE, FROM MARKER GO LEFT 70 MILS AND DOWN FROM THE SKYLINE AT THAT POINT 12 MILS. THIS WILL PLACE YOU ON A WHITE ROCK. THAT IS THE CAVE ENTRANCE.

d. When targets are being selected, careful consideration should be given to prescribed safety limits. No target should be assigned so close to a boundary that a reasonable bracket (200 meters) cannot be obtained. It is imperative that the officer in charge of firing insure that the first round fired will land in the impact area. When firing is to be conducted at long ranges and under unfavorable weather conditions, the range error resulting from velocity error and effects of met conditions may at

times exceed 10 percent of range. This potential error also makes the use of time fire hazardous until after registration corrections are obtained. The best data available should always be used.

e. After the target has been identified, the observer should be given enough time to prepare initial data; 2 minutes is normally adequate in the early stage of training. The first mission should be fired against a target of opportunity to create an air of realism. Registration can follow. For safety reasons, targets selected prior to a registration should be located near the center of the impact area. All observer personnel should prepare initial data for each mission and keep a record of the missions fired.

28-7. Supervision of Firing

a. The officer in charge must instill confidence in observer personnel and arouse and maintain interest in the service practice. He must take maximum advantage of time and ammunition to teach proper observer procedures. The officer in charge must enforce silence of the personnel on the observation post during a mission so that the observer is not distracted.

b. The observer must understand that the successful completion of the mission is his responsibility. A good policy is for the officer in charge not to interfere with the conduct of a mission unless safety is jeopardized, ammunition is in short supply, or repeated errors are made which, if continued, would decrease the instructional value of the mission. In such cases, the officer in charge may give help or he may reassign or stop the mission.

c. The observer must spot the burst as soon as it occurs. The officer in charge should stress that ac-

curate firing data depends on accurate spottings and corrections by the observer.

28-8. Critiques

The officer in charge should conduct a constructive and impersonal critique immediately after each mission. The critique should be specific, limited to essentials, and conducted generally in the following order:

a. A restatement of the assigned mission.

b. A statement that the mission was completed in a satisfactory (unsatisfactory) (excellent) manner or was not completed.

c. A concise analysis of the mission. Points of instructional value should be stressed. The good points of the mission and then the undesirable features should be stated. Violations of procedure should be pointed out, and the fact that adherence to prescribed procedures will always bring good results should be stressed. Recommendations for improvements should be made. The analysis should follow the sequence of the mission, but it should not be a round-by-round discussion.

d. A request for comments or questions.

28-9. Other Considerations

Service practices should be conducted from various observation posts with different impact areas being used. Periodically, service practice with maximum range and large angle T should be conducted to acquaint observers with the effects of dispersion. As the observer becomes proficient in the adjustment of fire, service practice should be conducted from tactical observation posts. Grading should include selection of approach routes, use of cover and concealment, and firing of the mission.

Section II. STANDARD TIMES FOR ARTILLERY FIRE

28-10. General

The mission of the artillery is to deliver accurate and timely fire in support of infantry and armor. If the mission is to be accomplished, certain standards of accuracy and speed must be met. Total times required for a mission measure the efficiency of a unit as a whole. A continuous program of timing by commanders should assist in locating and eliminating time losses. The ultimate goal must be to reduce the time required for a mis-

sion requiring an adjustment to the absolute minimum in order to make it closely approximate the effectiveness of fire without adjustment. This goal can be accomplished if commanders will constantly stress the necessity for timely determination of accurate initial data and the smooth, efficient functioning of all members of the artillery team.

28-11. Fire Mission Phases

The mission requiring an adjustment is only a substitute for the more effective surprise mission.

The adjustment results in a loss of surprise, and, consequently, the kill capabilities of a sudden volume of accurately placed fire. Adjustment requires prolonged use of wire and radio communication, thus inviting enemy jamming of radio and overloading of wire lines. In addition, as time for firing increases, exposure time to enemy counter-battery measures is increased. The mission requiring adjustment can be divided into three phases—first, the initial data phase; second, the adjustment phase; and third, the fire-for-effect phase.

a. The *initial data phase* starts when a target is seen or identified and ends when the first round of adjustment is on the way. During this phase, the target has not been alerted and urgency will depend on the nature of the target. For example, a target such as a column of infantry proceeding toward a point requires faster reaction than a target such as a command post. More time spent in this phase may reflect better initial data and, consequently, less time and fewer rounds for completion of the mission. However, when personnel are being trained under service practice conditions, stress must also be placed on speed in the initial data phase to emphasize the importance of speed in accomplishing the artillery mission.

b. The *adjustment phase* starts when the initial rounds land. From that instant on, the target is warned and evasive action can and will be taken.

c. The *fire-for-effect phase* starts when the observer commands FIRE FOR EFFECT and ends with completion of the mission. The fire-for-

effect rounds should normally follow the last rounds of adjustment as quickly as possible.

28-12. Standards of Proficiency

a. Timing standards should only be used as a guide in measuring the overall efficiency of a field artillery unit. Accuracy must not be sacrificed to obtain speed. Faster adjustments and reduction of exposure time depend on—

- (1) Improving initial data.
- (2) Decreasing the number of adjusting rounds required.
- (3) Speeding the action of personnel through better training and elimination of lost motion.

b. The timing standards contained in table 28-1 are based on average terrain and weather conditions, impact fuze in adjustment, impact or VT fuze in fire for effect, the initial data being within 400 meters of the target, a time of flight not greater than 25 seconds, and observer distance of 3,000 meters or less. Although no standard times are given for weapons other than 105-mm and 155-mm howitzers, the times listed can be used as a guide for all artillery pieces. The only change required for other artillery pieces will be to allow more time for loading and laying the larger cannons and usually for longer times of flight.

Note. The standards in table 28-1 do not separate telephone and radio operator time intervals. The efficiency of operators can be judged by the number of read-backs required. If communications personnel are not efficient, the total time standards will not be met.

Table 28-1. Standards of Proficiency (Speed) for Artillery Fires

Type of fire	Element	Event timed	Weapon	Standards—minutes and seconds			
				Superior	Excellent	Very satisfactory	Satisfactory
Observer.		Determination and transmission of initial data. (Time from last word of target identification to last element of observer's call for fire.)	Note 3----	01 00	01 30	02 00	02 30
		Per group of rounds, determination and transmission of corrections. (Time from last burst to last element of observer's correction.)	Note 3----	00 10	00 15	00 18	00 27

See footnote at end of table.

Table 28-1. Standards of Proficiency (Speed) for Artillery Fires—Continued

Type of fire	Element	Event timed	Weapon	Standards—minutes and seconds			
				Superior	Excellent	Very satisfactory	Satisfactory
Area fire.	Fire direction center.	Plotting target and determination of firing data for initial rounds. (Time from last element of observer's call for fire to quadrant command to battery.)	Note 3----	00 30	00 45	01 00	01 15
		Per group of rounds, determination of firing data subsequent to initial rounds. (Time from last element of observer's correction to quadrant command to battery.)	Note 3----	00 15	00 20	00 25	00 30
		Mass battalion after FFE is ordered by observer. (Time from observer's FFE to SHOT for the last battery.)	Note 1---- Note 2----	00 42 00 57	00 52 01 07	01 02 01 17	01 12 00 27
	Firing battery.	Initial rounds in adjustment. (Time from FDC quadrant to SHOT.)	Note 1---- Note 2----	00 15 00 30	00 20 00 35	00 25 00 40	00 30 00 45
		Per group of rounds, subsequent to initial rounds. (Time from FDC quadrant to SHOT.)	Note 1---- Note 2----	00 10 00 25	00 15 00 30	00 20 00 35	00 25 00 40
		FFE, battery one round. (Time from FDC quadrant to SHOT for the last round.)	Note 1---- Note 2----	00 15 00 30	00 20 00 35	00 25 00 40	00 30 00 45
	Overall firing time.	Time from first SHOT to SHOT for the last round in FFE. (Based on four groups of rounds in adjustment.)	Note 1---- Note 2----	04 25 05 25	05 17 06 17	06 09 07 09	07 01 08 01
Precision registration.	Observer.	Determination and transmission of initial data. (Time from last word of target identification to last element of observer's call for fire.)	Note 3----	01 00	01 30	02 00	02 30
		Per round, determination and transmission of corrections. (Time from burst to last element of observer's correction.)	Note 3----	00 10	00 13	00 16	00 19
		Per round in FFE, determination and transmission of spotting. (Time from burst to last element of observer's spotting.)	Note 3----	00 08	00 11	00 14	00 17
	Fire direction center.	Plotting target and determination of firing data for initial round. (Time from last element of observer's call for fire to quadrant command to battery.)	Note 3----	00 30	00 45	01 00	01 05
		Per round, determination of firing data subsequent to initial round. (Time from last element of observer's correction to quadrant command to battery.)	Note 3----	00 15	00 20	00 25	00 30
	Firing battery.	Initial round in adjustment. (Time from FDC quadrant to SHOT.)	Note 1---- Note 2----	00 15 00 30	00 20 00 35	00 25 00 40	00 30 00 45
	Overall problem time.	Adjustment only. (Time from first SHOT to SHOT for first round in FFE (based on four rounds in adjustment).)	Note 1---- Note 2----	04 00 05 00	04 52 05 52	05 44 06 44	06 36 07 36

See footnote at end of table.

MPI or HB registration.	Overall firing time.	Per round fired. (Time from SHOT to next	Note 1----	01 00	01 15	01 30	01 45
		SHOT. Includes report of instrument	Note 2----	01 15	01 30	01 45	02 00
		readings from two OP's.)					
		Total registration time. (Time from first	Note 1----	07 00	08 45	10 30	12 15
		SHOT to last OP report of registration.)	Note 2----	08 45	10 30	12 15	14 00
Fire for effect without adjustment.	Overall problem time.	Battery mission. (Time from last element of	Note 1----	00 45	01 00	01 15	01 30
		CALL FOR FIRE to SHOT.)	Note 2----	01 00	01 15	01 30	01 45
		Battalion mission. (Time from last element	Note 1----	00 57	01 12	01 27	01 42
		of CALL FOR FIRE to SHOT for last	Note 2----	01 12	01 27	01 42	01 57
		battery to fire.)					

Note 1—105-mm howitzer. Note 2—155-mm howitzer. Note 3—Both 105-mm and 155-mm howitzers.

c. Table 28-2 is a detailed breakdown of timing averaged for the "excellent" column, for area fire, in table 28-1.

Table 28-2. Service Practice Timing

From—	To—	Time interval (in seconds)
Target identified.....	Observer ready with call for fire.....	74
Observer initiates call for fire.....	Observer completes call for fire.....	16
Observer completes call for fire.....	Deflection sent to pieces.....	38
Deflection sent to pieces.....	Quadrant sent to pieces.....	7
Quadrant sent to pieces.....	Quadrant announced by chiefs of sections.....	5
Quadrant announced by chiefs of sections.....	Last chief of section reports READY.....	13
Last chief of section reports READY.....	Pieces are fired.....	2
(Pieces are fired.).....	(SHOT announced to observer.).....	(4)
Target identified.....	Pieces are fired.....	155
Initial rounds burst in target area.....	Observer completes subsequent corrections.....	15
Observer completes subsequent corrections.....	Deflection sent to pieces.....	14
Deflection sent to pieces.....	Quadrant sent to pieces.....	6
Quadrant sent to pieces.....	Quadrant announced by chiefs of sections.....	4
Quadrant announced by chiefs of sections.....	Last chief of section reports READY.....	8
Last chief of section reports READY.....	Pieces are fired.....	3
Initial rounds burst in target area.....	Subsequent rounds or fire for effect rounds are fired...	50

CHAPTER 29

DUTIES OF THE SAFETY OFFICER

29-1. General

At all times, safety is a command responsibility. Under peacetime conditions, safety officers are required to assist commanders in satisfying this responsibility. The safety officer normally should be a regularly assigned officer of that battery in order that there will be no divided responsibility between battery and battalion levels. Proficiency in the functioning of the safety officer should be treated in the same light as proficiency in the functioning of the battery executive. In either case, low standards dissipate the required sense of urgency and result in slow firing. The safety officer has two principal duties. First, he must insure that the pieces are laid and loaded so that the rounds, when fired, will land in the prescribed impact area. Second, he must insure that all safety precautions are observed at the firing point. While serving as safety officer, he will not be assigned other duties. Particularly, he will not be required to check the accuracy of the gun crews beyond that required to insure that bursts impact in the designated impact area.

29-2. Duties of Safety Officer Before Firing

Before firing is begun, the safety officer must—

- a. Verify that the safety card applies to the unit, exercise, date, and time.
- b. Verify that the battery is in the position specified on the safety card.
- c. Prepare a safety diagram.
- d. Check the pieces for boresighting.
- e. Verify the laying of the battery.
- f. Verify the minimum quadrant elevations determined by the executive officer. Compare the executive's minimum quadrant elevation with the quadrant elevation for minimum range on safety diagram, using the larger of the two as the minimum quadrant elevation.

g. Supervise the placing of safety stakes.

h. Verify that ammunition to be fired is the type specified on the safety card.

i. Insure that the chiefs of sections are informed of maximum and minimum quadrant elevations, right and left limits, and minimum fuze settings.

j. Verify that range clearance has been obtained.

k. Ascertain that the visible portion of the range is clear of personnel.

l. Insure that Department of the Army regulations, post regulations, and local special instructions pertaining to safety are complied with.

29-3. Duties of Safety Officer During Firing

After his preliminary checks are made, the safety officer should indicate that from the point of view of safety the battery is ready to fire. During firing, the safety officer will—

a. Verify the serviceability of ammunition.

b. Insure that the charge, projectile, and fuze being fired are limited to those prescribed on the safety card.

c. Insure that rounds are not fired below minimum quadrant elevation nor above maximum quadrant elevation for the charge being fired.

d. Insure that rounds are not fired outside the lateral safety limits.

e. Insure that time fuze rounds are not fired with fuze settings below the minimum prescribed on the safety diagram.

f. Instruct the executive officer not to fire until the safety officer has given a positive indication that it is safe to fire.

g. Command UNSAFE TO FIRE on all commands which are unsafe to fire and give the reasons therefor. Two examples are—

(1) UNSAFE TO FIRE, 3 MILS OUTSIDE RIGHT SAFETY LIMIT AND 20 MILS ABOVE MAXIMUM QUADRANT ELEVATION.

(2) UNSAFE TO FIRE, 5 MILS BELOW MINIMUM QUADRANT ELEVATION.

h. Apply registration corrections to the safety limits immediately after registration.

i. Report accidents and malfunctions of ammunition to the officer in charge of firing, request ambulance if needed, and be prepared to make a report as indicated in AR 700-1300-8.

j. Bring to the attention of the executive officer any unsafe conditions observed and suspend firing until the conditions have been corrected.

Examples of unsafe conditions are—

- (1) Safety features of piece not operable.
- (2) Propellant increments exposed to flames.
- (3) Personnel smoking near pieces.
- (4) Improper handling of ammunition.
- (5) Fuzes and projectiles stored together.
- (6) Time fuzes previously set and not reset to safe.
- (7) Primer inserted before the breech is closed (separate-loading ammunition).
- (8) Failure of cannoneer to inspect the propellant chamber and bore after each round fired.
- (9) Failure of cannoneer to swab the propellant chamber after each round of separate-loading ammunition fired.

29-4. Misfire

A misfire is sometimes the result of a mechanical failure and sometimes the result of a human failure. Whatever the cause, when a misfire has occurred, the action required in AR 385-63 must be observed.

29-5. Safety Card

a. A safety card which prescribes the hours of firing, the area in which the firing will take place, the location of the gun position, the limits of the impact area (in accordance with AR 385-63), and other pertinent data is approved by the range officer and sent to the officer in charge of firing. The officer in charge of firing gives a copy of the card to the safety officer,

who constructs a safety diagram based on the prescribed limits.

b. There is no prescribed format for the safety card; however, the format shown below generally is used.

★Safety limits for: 155-mm how M109, sh HE fz M564, M514, M557.

Firing point: 8632196586.

Reference point: GN; grid az—approx: 0.

Left limit: AZ 4730.

Right Limit: AZ 5450.

Minimum range: 4,300 meters.

Maximum range: 8,000 meters.

Special instructions: Use only chg 5 GB with this card. From az 4730 to az 5030, maximum range is 7,000 meters.

29-6. Safety Diagram

a. The safety officer, on receipt of the safety card, constructs a safety diagram. The diagram need not be drawn to scale but must accurately list the piece settings which delineate the impact area; the diagram serves as a convenient means of checking the commands announced to the gun crews against those commands which represent the safety limits. The diagram shows the right and left limits, expressed in deflections corresponding to those limits; the maximum and minimum quadrant elevations; and the minimum fuze settings (when applicable) for each charge to be fired. The diagram must not be cluttered with unnecessary information. Maximum fuze settings are not necessary, since a projectile fired with too great a fuze setting but with the proper maximum elevation would result in an impact burst within safety limits for range.

b. The basic safety diagram is a graphical portrayal of the data on the safety card. On the basic safety diagram are shown the minimum and maximum range lines; the left, right, and intermediate (if any) azimuth limits; the deflections corresponding to the azimuth limits; and the direction in which the battery is laid. The deflection limits are computed by comparing the azimuth on which the battery is laid to the azimuth limits and applying the difference to the counter reset deflection.

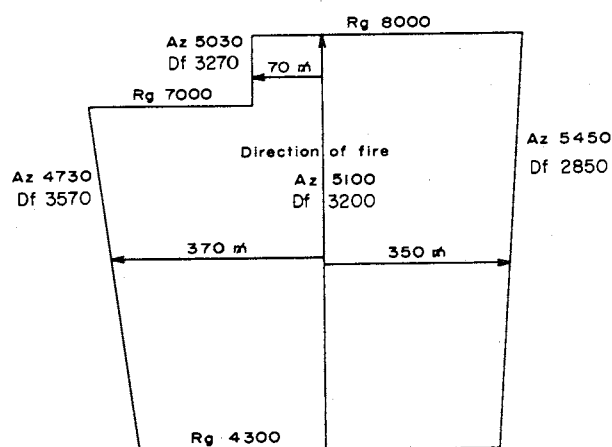
Example: A 155-mm howitzer M109 battery is laid on azimuth 5100. Counter reset deflection is 3,200 mils. The safety card for the position occupied is that shown in paragraph 29-5b. The basic safety diagram for this situation is shown in figure 29-1.

c. Unless a registration has been fired and corrections have been applied, all rounds must be fired in the central portion of the impact area.

29-7. Minimum Quadrant Elevation (Low-Angle Fire)

The minimum QE is computed for each authorized charge. The minimum QE consists of the following elements:

a. *Site to Highest Point on Minimum Range Line.* The highest point on the minimum range line is determined by plotting the minimum range line on a map and inspecting for the altitude of the highest point.



★Figure 29-1. Basic safety diagram.

Note. If an isolated peak causes an unnecessary limitation along the minimum range line, a separate site is computed and only the firing in the immediate area of the peak is limited by the minimum quadrant elevation determined for the peak.

b. *Elevation for Minimum Range.* If corrections are known, the corrections must be applied when the elevation is computed.

29-8. Minimum Fuze Setting (Low-Angle Fire)

The minimum fuze setting for time fuzes is the fuze setting corresponding to the elevation for minimum range plus the fuze correction (if known). The minimum fuze setting for VT fuzes is the time of flight corresponding to the elevation for minimum range plus 5.5 seconds. If the sum is not a whole number, the minimum safe time for VT fuzes is the next higher whole second.

29-9. Maximum Quadrant Elevation (Low-Angle Fire)

The maximum QE for each authorized charge is the sum of the following elements:

a. Site to the lowest point on the maximum range line.

b. Elevation for the maximum range. If corrections are known, the corrections must be applied when the elevation is computed.

29-10. Deflection Limits

After a registration has been fired, the deflection limits of the basic safety diagram must be corrected by adding the total deflection correction to each deflection limit.

29-11. Sample Problem

a. *Prior to Registration.*

Given:

Safety card (para 29-5b).

Basic safety diagram (fig. 29-1).

Altitude of battery 390 meters.

Altitude of highest point at minimum range 411 meters.

Altitude of lowest point at maximum range (right) 405 meters.

Altitude of lowest point at maximum range (left) 410 meters.

Find:

Minimum QE, minimum fuze setting (time), and maximum QE.

Solution:

Minimum QE:

Altitude of highest point at minimum range. 411 meters.

Altitude of battery 390 meters.

Vertical interval +21 meters.

Site (+21/4300, GST)	+5 mils.
Elevation (charge 5 green bag, GFT).	196 mils.
Minimum QE	201 mils.
★Minimum fuze setting for fuze M564:	
★Fuze setting corresponding to minimum elevation.	13.4
Minimum fuze setting for fuze M514:	
Time of flight corresponding to minimum elevation.	13.5
	+5.5
	19.0

Minimum fuze setting for fuze M514 is 19.0 seconds.

Maximum QE (right segment):	
Lowest altitude at maximum range.	405 meters.
Altitude of battery	390 meters.
Vertical interval	+15 meters.
Site (+15/8000, GST)	+2 mils.
Elevation (Charge 5 green bag, GFT).	447 mils.
Maximum QE (left segment):	
Lowest altitude at maximum range.	410 meters.
Altitude of battery	390 meters.
Vertical interval	+20 meters.
Site (+20/7000, GST)	+3 mils.
Elevation (Charge 5 green bag, GFT).	365 mils.
Maximum QE	368 mils.

★b. After Registration.

Given:

GFT setting is GFT A: Charge 5, lot XY, range 6,000, elevation 315, time 20.4. Total deflection correction, right 8 mils.

Find:

Minimum QE, minimum fuze setting, and maximum QE.

Solution:

Minimum QE:	
Site to highest point at minimum range.	+5 mils
Elevation (GFT)	208 mils
Minimum QE	213 mils
Minimum fuze setting for fuze M564:	
Fuze setting at minimum range (GFT).	13.9
Minimum fuze setting for fuze M514:	
Time of flight corresponding to elevation 208.	14.3
	+5.5
	19.8

Minimum fuze setting for fuze M514 is 20.0 seconds.

Maximum QE (right segment):	
Site to lowest point at maximum range.	+2 mils
Elevation (GFT)	482 mils
Maximum QE	484 mils
Maximum QE (left segment):	
Site to lowest point at maximum range.	+3 mils
Elevation (GFT)	391 mils
Maximum QE	394 mils

Deflection Limits	Left	Intermediate	Right
Basic deflection limits	3570	3270	2850
Deflection correction	R8	R8	R8
New deflection limits (mils).	3562	3262	2842

Note. Graphical equipment is used to determine elevations, sites, and fuze settings for the fuze M564 when ranges permit its use; otherwise, tabular equipment is used. Data are determined to the same accuracy as that for firing.

29-12. Construction of Safety Diagram From Visible Reference Point

Occasionally, a safety card will specify a reference point instead of an azimuth and the lateral limits by angular measurements right and left of that reference point. The procedure for preparing the safety diagram is as follows:

a. Use the following information from the safety card:

Reference point: Blockhouse Signal Mountain.

Left limit: 350 mils left.

Right limit: 200 mils right.

b. After the pieces are laid and the collimator is placed out, determine the smallest angle between the line of fire and the reference point by using the azimuth counter on the panoramic telescope of the base piece as an angle-measuring instrument. (Assume that the battery has been laid, the collimator has been placed out at deflection 2600, and an angle of 100 mils has been measured from the line of fire to the reference point.)

Note. Since the panoramic telescope measures only clockwise angles, those measured to the left of the line

of fire are determined by subtracting the reading on the azimuth counter of the sight from 3200. Angles measured to the right of the line of fire are determined by subtracting 3200 from the reading on the azimuth counter of the sight. In this example, measuring to the reference point would produce a reading of 3100 (3200 minus 100 equals 100 mils).

c. Using the LARS rule (left, add; right, subtract), determine the proper deflection to lay the pieces on the reference point (deflection 3200, left 100, equals deflection 3100).

d. Again using the LARS rule, apply the right and left angular measurements from the reference point specified on the safety card to the deflection required to lay on the reference point (fig. 29-2).

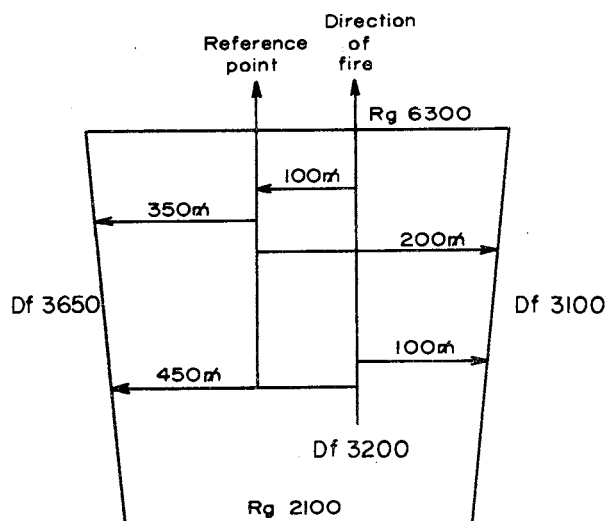


Figure 29-2. Safety diagram from visible reference point.

(1) Left limit: From deflection 3300, left 350 equals deflection 3650.

(2) Right limit: From deflection 3300, right 200 equals deflection 3100.

e. If the reference point is not visible because of weather conditions, the azimuth to the reference point, if not given on the safety card, must be computed by using the grid coordinates of the reference point. The pieces may then be laid on that azimuth or on any other convenient azimuth.

29-13. Special Situations

a. *High-Angle Fire.* When high-angle fire is employed, the safety limits are computed in the following manner:

(1) *Maximum quadrant elevation.* The maximum QE for *minimum* range is the sum of the elevation (to the nearest mil) for minimum range and the site (to the nearest mil) to the highest point on the minimum range line.

(2) *Minimum quadrant elevation.* The minimum QE for *maximum* range is the sum of the elevation (to the nearest mil) for maximum range and the site (to the nearest mil) to the lowest point on the maximum range line.

(3) *Deflection limits.* When high-angle fire is employed, the deflection limits on the basic safety diagram are always modified to consider the drift. The right deflection limit is moved to the left by the amount of the maximum drift for the cannon for the charges being fired. The left deflection limit is moved to the left by the amount of the *minimum* drift for the cannon for the charges being fired. After a high-angle registration, the deflection limits are further modified by the amount of the deflection correction.

★b. *Illuminating Projectile.* When illuminating projectile is employed, the safety diagram is computed as for HE in low angle fire except as follows:

(1) When the GFT is used, the minimum and maximum quadrant elevations are determined as for shell HE using the elevation to impact scale.

(2) When the tabular solution is used, the minimum quadrant elevation is determined by lowering the height of burst, in 50 meter increments, to the highest point on the minimum range line. The range to impact column is used to determine the maximum quadrant elevation to the lowest point on the maximum range line. The range to impact column indicates where the projectile will impact in the event detonation does not occur prior to achieving that range.

★ *Note.* Tests are presently being conducted to determine the debris area for the illuminating projectile. When these data are available they will be included in the tabular firing table for each range and charge.

c. *Heavy Artillery.* Because of the great range and resulting large amount of drift when heavy artillery is being fired at long range, drift for low-

angle fire must be considered in computation of data for safety limits before registration or before otherwise determining corrections.

29-14. Safety Stakes

a. Safety stakes for each piece are an aid to the safety officer in checking lateral limits. The stakes are placed approximately 10 meters forward of each piece along the lateral limits specified on the safety card. By standing to the rear of a piece and glancing along the tube, the safety officer can easily see whether the tube is pointed close to the lateral safety limits. When the tube approaches the limits, the safety officer makes a careful check on the deflection set on the piece and on the actual laying of the tube.

b. The best method for placing safety stakes is to traverse the tube to the lateral limits and sight through the tube to install the safety stakes.

c. Another method for placing safety stakes (fig. 29-3) is as follows: Lay the tube in the direction in which the battery was initially laid. From the safety card, determine the angles (right and left) from this direction of fire to the right and left limits. Using the reset counter on the panoramic telescope, set off the angles from the direction of fire to the deflection limits and aline the safety stakes with the vertical hairline.

d. For inclosed, self-propelled weapons, various aids to safety are used, since safety stakes cannot be seen from the piece. One method is to mark the deflection limits on the turret azimuth scale in chalk. The unit's SOP should indicate the approved method for the piece.

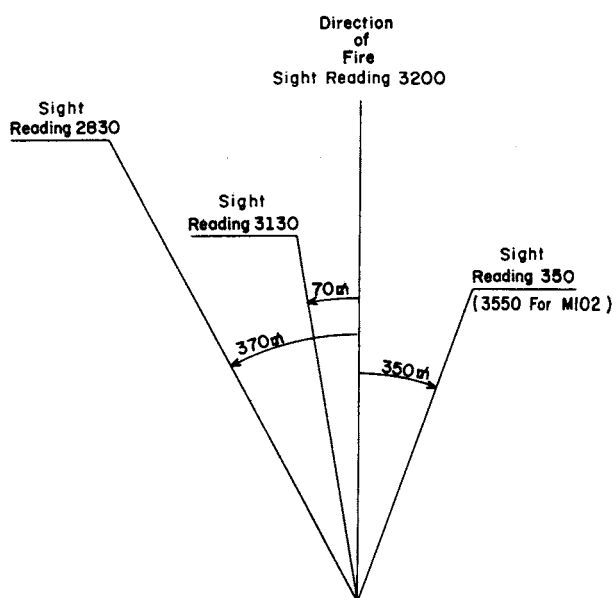


Figure 29-3. Safety stake diagram based on basic safety diagram.

CHAPTER 30

NUCLEAR DELIVERY TECHNIQUES FOR CANNON ARTILLERY

Section 1. 8-INCH HOWITZER—NUCLEAR DELIVERY

30-1. General

a. Procedure. This section describes direction technique for delivery of the 8-inch howitzer nuclear round. Nuclear delivery techniques for the 8-inch howitzer are the same as those for standard gunnery procedures with the exception of the determination of the fuze setting and the addition of ballistic corrections for the nuclear round.

b. Nomenclature.

(1) The high-explosive spotting round (HES M424) is used for registrations and adjustments.

(2) The nuclear round (NUC M422) is used for fire for effect.

c. Preferred Techniques. The two preferred techniques for the delivery of nuclear rounds from an 8-inch howitzer are—

- (1) Met plus VE.
- (2) K-transfer (GFT).

d. Fire-for-Effect Technique. If the information necessary for the employment of a preferred technique is not available, an adjustment and fire-for-effect (observer adjustment) technique may be used.

30-2. Requirements for Delivery Techniques

The requirements for the use of the various delivery techniques of 8-inch nuclear rounds are as follows:

a. Met Plus VE.

- (1) Accurate survey data for the gun and target.
- (2) Registration data for shell HES.
 - (a) Valid velocity error.
 - (b) Valid deflection correction.
 - ★(c) Valid fuze correction.
- (3) Current met data.

b. K-transfer (GFT).

(1) Accurate survey data for the gun and target.

★(2) Valid GFT setting, total fuze correction, and total deflection correction.

c. Observer Adjustment. Observer in position to observe.

30-3. Accuracy

All firing data are determined to the same accuracy as that required for standard gunnery procedures.

30-4. Selection of Delivery Technique

a. Considerations in Selection of Delivery Technique. Listed below are some of the considerations in the selection of a delivery technique. The S3 must evaluate all considerations in making his decision.

- (1) Tactical situation.
- (2) Commander's guidance.
- (3) Desirability of surprise.
- (4) Weather conditions.
- (5) Availability of spotting rounds.
- (6) Time available.
- (7) Registration restrictions.
- (8) Survey.
- (9) Validity of GFT setting, velocity error, deflection, and total fuze correction.

b. Registrations. In a nuclear war, it is anticipated that the unit will register (three-round high burst) at least one weapon with shell HES immediately after occupying the position. This registration will establish a VE to be used in the met plus VE technique and a GFT setting for the K-transfer method. After this registration, the S3 will have three options ((1) through (3) below) for delivery of

fire on a target. The selection of the technique is based on the considerations listed in *a* above.

(1) Met plus VE.

(2) K-transfer.

(a) Use registration data if still current.

(b) Reregister if data are not current.

(c) Use GFT setting updated with current met message plus VE.

(3) Observer adjustment.

c. Accuracy of Techniques. The accuracy of each technique is dependent on some of the same considerations listed in *a* and *b* above. There are so many variables that one technique cannot be considered as the most accurate technique under all conditions. General guides are as follows:

(1) The met plus VE technique will probably be the most accurate method under most conditions. This is particularly true when the target is in a fringe area or outside the transfer limits or the registration data are not current. The accuracy of this technique is dependent on the validity of the met messages and the accuracy of the target location.

(2) The K-transfer method using current registration data will yield an accurate solution. If the target is accurately located and in proximity to the high-burst registration, the accuracy should equal or, possibly, exceed that of the met plus VE technique. In the fringe areas of the transfer limits or outside the transfer limits, the accuracy can be expected to decrease. The principal disadvantage of this system is that a registration will usually have to be fired to develop current data.

(3) The observer adjustment technique is the least desirable method for several reasons. The accuracy of this technique is dependent on the ability of the observer to see the effect of the burst on the ground and the size of the observer's bracket. This technique is used when the other techniques cannot be used. The disadvantages are the time consumed, loss of surprise, requirement for an observer to be in position, inaccuracy of fire (normally 100-meter bracket split), and number of rounds (HES) used in adjustment.

d. Time Requirements. The time required to prepare fire commands to fire a nuclear round

is dependent on the data available. If a current GFT setting is available, the K-transfer technique will be the fastest. The next most rapid solution is met plus VE. The K-transfer technique will be the slowest if a registration must be fired, because of the time required to register. The observer adjustment technique is dependent on the speed of adjustment.

★*e. Ballistic Corrections.* Except for the ballistic correction (table M), the 8-inch howitzer firing tables used for nuclear delivery are constructed for projectile HES (M424). Because of ballistic differences, a spotting round (HES M424) and a nuclear round (NUC M422) fired with the same data will not burst at the same point. When the nuclear projectile is to be used, the quadrant elevation and fuze setting for the projectile HES must be corrected by the amount of ballistic corrections determined from the firing table. The firing tables are entered with the final quadrant elevation (QE) for projectile HES rounded to the nearest listed value in the table and the height of burst above gun to the nearest 1 meter. Corrections to QE are determined to the nearest 1 mil; corrections to fuze setting, to the nearest 0.1. These values can usually be visually interpolated.

f. Determination of Total Fuze Correction.

(1) The large vertical intervals involved in the delivery of nuclear rounds necessitate the consideration of the complementary angle of site (complementary range) in the determination of the total fuze correction. A larger fuze setting is required to deliver a projectile to a point at a given range plus a 200-meter vertical interval than to a point at the same range at the same altitude. This difference in fuze setting is in direct relationship to the complementary angle of site (complementary range). This is true in the delivery of conventional high-explosive (HE) projectiles for all weapons. However, in firing conventional HE, the vertical intervals and complementary angles of site are normally small; consequently, there is a negligible effect on the fuze setting. The procedure for determining the total fuze correction is as follows:

(a) Determine the angle of site and site (GST).

(b) Determine the complementary angle of site (site minus angle of site).

(c) Determine the fuze setting for the adjusted elevation plus the complementary angle of site (GFT).

(d) Subtract the fuze setting for the adjusted elevation plus the complementary angle of site from the adjusted fuze setting. The procedure for determining the total fuze correction with the tabular firing tables is the same except that the elevation plus complementary angle of site is determined by adding the complementary range to the chart range for the achieved high-burst (HB) location and interpolating for elevation plus complementary angle of site in table F of the firing tables.

(2) The following illustrates the determination of the total fuze correction with the GFT and GST (charge 1, projectile HES): Chart data to high burst location:

Range	3,490 meters.
Height of burst above gun	+ 162 meters.
Adjusted Data for the high burst:	
QE	389 mils.
Fuze setting	15.9.
Total fuze correction:	
Fuze setting fired	15.9.
Site to high burst (+ 162/ 3490; chg 1, TAG, GST)	+ 53 mils.
Angle of site (+ 162/3490; C and D scales GST)	+ 47 mils.
Comp site (+ 53 — (+ 47))	+ 6 mils.
Adjusted elevation (389 — (+ 53))	336 mils.
Adjusted elevation plus comp site (336 + (+ 6))	342 mils.
Fuze setting for adjusted elevation plus comp site (GFT) ..	16.5
Total fuze correction (15.9— 16.5) ..	—0.6.

(3) When the total fuze correction is applied to a target, it must be added to the fuze setting for the elevation plus complementary angle of site to the target.

g. Velocity Error.

(1) Velocity error (VE) includes the total deviation from standard for the weapon, ammunition, firing chart, and survey which cannot be accounted for or corrected except by firing. The following factors in relation to VE for nuclear delivery must be considered:

(a) Nuclear delivery units will have a higher survey priority than other units.

(b) Registrations may be fired only once, if at all, for each position.

(c) Manufacturer's tolerances are less for the spotting and nuclear rounds than for conventional ammunition.

(2) Accordingly, the VE is continually averaged at every opportunity. Judgment must be used in the continual averaging of these velocity errors. A large deviation of a new VE from the average VE should be viewed critically, and the error corrected or the reason for the error determined and isolated. If the reason cannot be determined, it is usually better to omit this VE when the average is being computed.

30-5. Met Plus VE

a. Determination of Velocity Error, Fuze Correction, and Total Deflection Correction. The VE and total deflection correction for shell HES are determined by following the same procedure used for determining the VE and total deflection correction for HE as described in chapter 21. The VE and total deflection correction for nuclear delivery should be determined as soon as possible after occupation of position and should not be delayed until the receipt of a nuclear mission.

b. Determination of the Fuze Correction. The fuze correction is determined as outlined in chapter 21 except that comp site must be taken into account as outlined in paragraph 30-4.

30-6. Example-Determination of Velocity Error, Deflection Correction, and Fuze Correction

a. Chart Data to Point Selected for High Burst.

Deflection	3,148 mils
Range	9,820 meters
Height above gun	+ 180 meters

★b. Determination of Firing Data for High-Burst Registration (Charge 3, Shell HES).

(1) It is mandatory that the first round of the high burst be observed. Therefore, the firing data for the high burst must reflect as many of the known nonstandard conditions as possible. The VE of the weapon and current met data should be applied to the firing data.

(2) *QE to be fired.*

Total range correction based on VE
and current met -160 meters
Elevation for the corrected range
(9820—(+160)) 306 mils
Site (+180/9820; chg 3, TAG, GST) +20 mils
QE (306 + (+20)) 326 mils

(3) *Fuze setting to be fired.*

Angle of site (+180/9820; C and D
scales, GST) +19 mils
Comp site (+20 — (+19)) +1 mil
Elevation plus comp site :306 + (+1) 307 mils
Fuze setting 27.3
Met fuze correction 0

(4) *Deflection to be fired.*

Current met deflection correction R4 mils
Deflection (3148—R4) 3144 mils

(5) The firing data in (2) and (3) above may be determined from the tabular firing tables by using the complementary range table to determine the entry range. The entry range is used to determine the elevation plus complementary angle of site and the fuze setting. The angle of site is added to the elevation plus complementary angle of site to determine the quadrant elevation.

c. Chart Data to the Achieved High-Burst Location (Graphic Solution or Computed).

Deflection 3,147 mils
Range 9,520 meters
Height of burst above gun +157 meters

** d. Determination of the Total Range Correction.*

QE fired 326 mils
Site (+157/9520; chg 3, TAG, GST) +18 mils
Adjusted elevation (326—(+18)) 308 mils
Range for elevation 308 (GFT) 9,700 meters
Total range correction (9700—9520) +180 meters

** Note.* The total range correction can be determined, using the tabular firing tables, by subtracting the range corresponding to the elevation plus complementary angle of site from the

entry range to the achieved high-burst.

e. Determination of the Total Fuze Correction.

Fuze setting fired 27.3
Fuze setting corresponding to elevation
plus comp site (309) 27.4
Total fuze correction (27.3—27.4) -0.1

f. Determination of the Total Deflection Correction.

Deflection fired 3,144 mils
Deflection to chart location of high-
burst 3,147 mils
HB registration deflection correction
(total deflection correction) R3 mils

** g. Determination of the Met Range Correction, Met Deflection Correction, and Met Fuze Correction (fig 30-1).*

Battery laid on azimuth, 2000, deflection
3200.

Azimuth fired 2,056 mils
Weight of projectile 244 pounds
Altitude of gun 326 meters
Altitude of burst 483 meters
Propellant temperature 66°F
Latitude of gun 34°N

Concurrent NATO met message:

METB39	MIFMIF	070550	049982		
002618	009976	012618	009978	022720	009978
032927	004981	042928	002982	053129	004987

h. Determination of Velocity Error and Fuze Correction. (fig. 30-1).

i. Determination of Position Deflection Correction.

Total deflection correction R3 mils
Met deflection correction R4 mils
Position deflection correction L1 mil

** j. Results.*

VE -1.3 m/s
Fuze correction 0
Position deflection correction L1 mil

MET DATA CORRECTION SHEET (FM 6-40)									
BATTERY DATA					MET MESSAGE				
CHARGE	ADJ QE	CHART RG	LATITUDE	TYPE MESSAGE	OCTANT	AREA/UNIT			
3	326	9520	30°N	METB 3	9	MIFMIF			
ACT OF BTRY (10 m)		330		DATE	TIME	ALT MDP	PRESSURE		
				07	0530	490	98.2		
ALT OF MDP		490		LINE NO.	WIND DIR	WIND SPEED	AIR TEMP	AIR DENSITY	
				03	2900	27	100.4	98.1	
BTRY ABOVE MDP (AN)		-160		A & B CORRECTION			0.3	1.6	
ALT OF TARGET (nearest meter)		483		CORRECTED VALUES			100.7	99.7	
HEIGHT OF BURST ABOVE TARGET		---							
ALT OF BURST		483							
ALT OF BTRY (nearest meter)		326							
HEIGHT OF TARGET (Burst) ABOVE GUN (M)		+157		COMP RG	CHART RG	ENTRY RG	9500		
				+22	9520	9542			
WIND COMPONENTS AND DEFLECTION									
WHEN DIRECTION OF WIND IS LESS THAN DIR FIRE ADD		6400		Total DF Corr R3					
DIRECTION OF WIND		2900		Met DF Corr R4					
				Pos DF Corr L1					
DIRECTION OF FIRE (2056)		2100		ROTATION CORR R 0.9					
CHART DIRECTION OF WIND		800		DRIFT CORR L 4.6					
CROSS WIND	WIND SPEED	27	COMP 0.71	0.19	KNOTS	0.48	CROSS WIND CORR	9.1	
RANGE WIND	WIND SPEED	27	COMP 0.71	0.19	KNOTS	0.48	MET DEF CORR	3.6 R4	
MET RANGE CORRECTION									
	KNOWN VALUES	STANDARD VALUES	VARIATIONS FROM STANDARD	UNIT CORRECTIONS	PLUS	MINUS			
RANGE WIND	19	0	19	+9.1	172.9				
AIR TEMP	100.7	100	0.3	-5.6		3.9			
AIR DENSITY	99.7	100	0.3	-33.5		10.0			
PROJ WEIGHT	244 Lbs	242 Lbs	2	+2.0	4.0				
ROTATION	-33 x 0.87					28.7			
						176.9			
						42.6			
						134.3	+134		
COMPUTATION OF VE									
PROP TEMP	66°	VE	-1.3	M/S	D +21.9	TOTAL RANGE CORRECTION	+180		
	CHANGE TO MV FOR PROP TEMP	AV	-0.8	M/S	I -21.3	MET RANGE CORRECTION	+134		
		AV	-2.1	M/S	MV UNIT CORRECTION +21.9	AV RANGE CORRECTION	+46		
						TOTAL RANGE CORRECTION			
OLD VE		NEW VE		AVG VE		M/S			
T1 27 MET FUZE CORRECTION									
	VARIATION FROM STANDARD	UNIT CORRECTION	PLUS	MINUS					
AV	2.1	-0.038		0.080					
RANGE WIND	19	-0.002		0.038					
AIR TEMP	0.7	-0.006		0.004					
AIR DENSITY	0.3	+0.044	0.013						
PROJ WEIGHT	2	-0.011		0.022	TOTAL FUZE CORRECTION	-0.1			
				0.013	MET FUZE CORRECTION	-0.1			
				0.013	FUZE CORRECTION	0			
				0.131	TOTAL FUZE CORRECTION				
MET FUZE CORR									
OLD FZ CORR		NEW FZ CORR		AVG FZ CORR					
TARGET NO.		BATTERY		DATE/TIME					
		B		070600 Mar 70					

DA FORM 6-15

REPLACES EDITION OF 1 MAY 66, WHICH WILL BE USED.

* Figure 30-1. Met data correction sheet (DA Form 6-15).

30-7. Application of Met Plus VE

a. The application of met plus VE is the same as for shell HE (chap 21) except for the fuze setting (use elevation plus comp site) and the ballistic corrections. When the met plus VE technique is used, the data will be computed to the target. The GFT setting will be kept current by use of met plus VE for emergencies, such as insufficient time to compute met plus VE to the target.

b. The ballistic corrections are determined as indicated in paragraph 30-8.

30-8. Example—Application of Met Plus VE

This problem is a continuation of the problem in paragraph 30-6.

a. Chart Data to Target.

Range	10,520 meters
Desired height of burst above gun	+150 meters
Deflection	3,248 mils

b. Solution of Met Message for Met Range Correction, Met Deflection Correction, and Met Fuze Correction (fig 30-2).

Weight of projectile	241 pounds
Propellant temperature	75 F
Altitude of battery	326 meters
Altitude of target	336 meters
Height of burst above target	+140 meters
Chart deflection to target	3,248 mils
Battery laid on azimuth	2,000 mils
Referred deflection	3,200 mils
VE	-1.3 m/s
Position deflection correction	L1 mil
Fuze correction	0
Charge	3
Current NATO message:	

METB39	MIFMIF	070750	049980		
004211	011970	014214	011971	024320	009971
034422	009973	004225	008973	054229	008972

★ *Note.* The line number to use in solving the met message can be determined by using table B. However, a more accurate determination can be made by inferring a QE and using table A. A QE can be inferred from the current GFT setting and the chart data to the target.

c. *Application of Velocity Error.* The application of VE to determine the total range correction is shown in figure 30-2.

★ d. Determination of Quadrant Elevation.

Total range correction	-200 meters
Chart range	10,520 meters
Corrected range (10,520 + (-200))	10,320 meters

Elevation for corrected range	342 mils
Site (+150/10,520, GST)	+16 mils
QE	358 mils
QE correction for ballistic difference	+9 mils
(Enter the Ballistic Correction table, table M in the tabular firing table, with the nearest listed QE and height of burst above gun to the nearest meter.)	
QE to be fired	367 mils

Note. The QE may be determined from the tabular firing tables by obtaining the elevation plus complementary angle of site for the total range correction plus the entry range (chart range plus complementary range) to the target and adding the angle of site. The ballistic correction still must be added to this quadrant elevation.

★ e. Determination of the Fuze Setting.

Angle of site (+150/10,520; C and D scales)	+15 mils
Comp site (+16-(-15))	+1 mils
Elevation plus comp site	343 mils
Fuze setting for elevation plus comp site	30.3
Fuze correction	0
Met fuze correction	+0.1
Total fuze correction	+0.1
Fuze setting (30.0 + 0.1)	30.1
Fuze correction for the ballistic difference	+0.4
(Enter the Ballistic Correction table, table M in the tabular firing table, with the nearest listed QE and height of burst above gun to the nearest meter.)	
Fuze setting to be fired	30.5

Note. The fuze setting may also be determined from the tabular firing tables by adding the fuze setting corresponding to the elevation plus complementary angle of site discussed in d above to the total fuze correction and the fuze correction for the ballistic difference.

f. Determination of Deflection.

Chart deflection	3,248 mils
Position deflection correction	L1 mil
Met deflection correction	R4 mils
Total deflection correction	R3 mils
Deflection to be fired	3,245 mils

★ g. Firing Data.

Deflection	3,245 mils
Fuze setting	30.5
QE	367 mils

30-9. K-Transfer GFT Technique

a. *General.* The K-transfer GFT technique consists of a GFT setting, a fuze correction, and a deflection correction. Corrections are determined from a HB registration, normally with three

rounds of HES shell. The ballistic difference between the spotting rounds and the nuclear round must be applied in the same manner as in the met plus VE technique. The differences, if any, between the weights of the projectiles and between the propellant temperatures of the spotting round and the nuclear round must also be applied.

b. Determination of GFT Setting. The GFT setting is determined in the same manner as for HE ammunition except that the total fuze correction replaces the time gage line.

c. Determination of Total Fuze Correction. Total fuze correction is determined by using the elevation plus complementary angle of site method as discussed in paragraph 30-4f.

d. Determination of Total Deflection Correction. Total deflection correction is determined in the normal manner by going from chart deflection to adjusted deflection and establishing a deflection correction scale. The transfer limits are the same as those for conventional HE ammunition.

e. Application of Data to a Target. The GFT setting is used in the conventional manner to determine the elevation. The GST is used to determine the site and the angle of site. The fuze setting is determined from the elevation plus complementary angle of site plus the total fuze correction. The quadrant elevation and fuze setting are corrected for the ballistic differences as indicated in paragraph 30-4e. The total deflection correction is determined from the deflection correction scale.

30-10. Example—Determination of GFT Setting, Total Fuze Correction and Total Deflection Correction

a. Known Data.

Shell	HES
Lot	XY
Charge	3
Weight of projectile	241 pounds
Propellant temperature	66° F
Altitude of battery	318 meters

b. Fired (Adjusted) Data for High-Burst Registration.

Deflection	3,239 mils
Fuze setting	26.7
QE	325 mils

c. Chart Data to High-Burst Location.

Deflection	3,235 mils
Range	9,370 meters
Height of burst above gun	+184 meters

d. Determination of GFT Setting.

Site (+184/9370; chg 3, TAG, GST)	+21 mils
Elevation (325 — (+21))	304 mils
GFT: Chg3, lot XY, RG 9370, el 304	

e. Determination of Total Fuze Correction.

Angle of site (+184/9370, C and D scale, GST)	+20 mils
Comp site (+21 — (+20))	+1 mil
Elevation plus comp site (304 + (+1))	305 mils
Fuze setting for elevation plus comp site (GFT)	27.1
Total fuze correction (26.7—27.1)	—0.4

f. Determination of Total Deflection Correction.

Adjusted deflection	3,239 mils
Chart deflection	3,235 mils
Registration deflection corrections (center of the deflection correction scale)	Left 4 mils

g. Results.

GFT: Chg 3, lot XY, rg 9370, el 304	
Total fuze correction	—0.4
Total deflection correction	Left 4 mils

30-11. Example—Application of K-Transfer Technique

This problem is a continuation of the problem in paragraph 30-10. Projectile weight (shell nuclear) is 240 pounds; current propellant temperature is 74° F.

MET DATA CORRECTION SHEET (FM 6-40)									
BATTERY DATA					MET MESSAGE				
CHARGE	ADJ QE	CHART RG	LATITUDE	TYPE MESSAGE	OCTANT	AREA/UNIT			
3		10,520	30°N	METB 3	9	MIFMIF			
ALT OF BTRY (10 m)		330		DATE	TIME	ALT MDP	PRESSURE		
				07	0730	490	98.0		
ALT OF MDP		490		LINE NO.	WIND DIR	WIND SPEED	AIR TEMP	AIR DENSITY	
				04	4200	25	100.8	97.3	
BTRY ABOVE/BELW MDP (ΔN)		-160		Δ N CORRECTION			0.3	1.6	
ALT OF TARGET (nearest meter)		336		CORRECTED VALUES			101.1	98.9	
HEIGHT OF BURST ABOVE TARGET		+140							
ALT OF BURST		476							
ALT OF BTRY (nearest meter)		326							
HEIGHT OF TARGET (burst) ABOVE GUN (M)		+150		COMP RG	CHART RG	ENTRY RG	10,500		
				+24	10,520	10,544			
WIND COMPONENTS AND DEFLECTION									
WHEN DIRECTION OF WIND IS LESS THAN DIR FIRE ADD		6400		Pos DF Corr L1					
DIRECTION OF WIND		4200		Met DF Corr R4					
				Total DF Corr R3					
DIRECTION OF FIRE (4952)		2000		ROTATION CORR 0 1.1					
CHART DIRECTION OF WIND		2200		DRIFT CORR L 5.5					
CROSS WIND	WIND SPEED	25	* COMP	0.83	21	KNOTS	0.52	CROSS WIND CORR	0.9
RANGE WIND	WIND SPEED	25	* COMP	0.56	14	KNOTS		MET DEFL CORR	4.3 R4
MET RANGE CORRECTION									
	KNOWN VALUES	STANDARD VALUES	VARIATIONS FROM STANDARD	UNIT CORRECTIONS	PLUS	MINUS			
RANGE WIND	14	0	14	-9.6		134.4			
AIR TEMP	101.1	100%	1.1	-8.5		9.4			
AIR DENSITY	98.9	100%	1.1	-37.9		41.7			
PROJ WEIGHT	24/ Lbs	242 Lbs	1	-1.0		1.0			
ROTATION	-35 * 0.87					30.4			
						216.9			
						216.9 -217			
COMPUTATION OF VE									
PROP TEMP	73°	VE	-1.3	M/S	D +23.0	TOTAL RANGE CORRECTION			
		CHANGE TO MV FOR PROP TEMP	+0.6	M/S	I -22.4	MET RANGE CORRECTION	-217		
		ΔV	-0.7	M/S	MV UNIT CORRECTION +23.0	ΔV RANGE CORRECTION	+16		
						TOTAL RANGE CORRECTION	-201 -200		
T1 30 MET FUZE CORRECTION									
	VARIATION FROM STANDARD	UNIT CORRECTION	PLUS	MINUS					
ΔV	0.7	-0.041		0.029					
RANGE WIND	14	+0.004	0.056						
AIR TEMP	1.1	-0.003		0.003					
AIR DENSITY	1.1	+0.050	0.055						
PROJ WEIGHT	1	+0.010	0.010						
				0.121	0.032	TOTAL FUZE CORRECTION	+0.1		
				0.032		FUZE CORRECTION	0		
				0.089		TOTAL FUZE CORRECTION	+0.1		
MET FUZE CORR									
OLD FZ CORR * NEW FZ CORR = * 2 = AVG FZ CORR									
TARGET NO.	BATTERY		DATE/TIME						
	B		070800 Mar 70						

DA FORM 6-15

REPLACES EDITION OF 1 MAY 66, WHICH WILL BE USED.

* Figure 30-2. Met data correction plus VE.

a. Chart Data to Target.

Range	10,470 meters
Deflection	3,132 mils
Altitude of target	341 meters
Desired height of burst above target	+150 meters

b. Determination of Entry Range. (Entry range is necessary for determination of unit corrections for projectile weight and propellant temperatures in *c* below. Visual interpolation usually is possible because entry range is used to the nearest 100 meters.)

Complementary range (enter table B at chart range and height of burst above gun)	+28 meters
Chart range	10,470 meters
Entry range	10,498 meters

*c. Determination of Corrections for Difference in Projectile Weight and Propellant Temperature.**(1) Correction for projectile weight.*

Weight of projectile (nuclear)	240 pounds
Weight of projectile used for registration	241 pounds
Variation from registration value	Decrease/1 pound
Unit correction determined at entry range (10,500)	—1 meter
Correction	—1 meter

(2) Correction for propellant temperature.

Change to muzzle velocity for current propellant temperature (74° F)	+0.8 m/s
Change to muzzle velocity for propellant temperature at registration (66° F)	—0.8 m/s
Variation from registration value	Increase 1.6 m/s
Unit correction (determined at entry range)	—22.4 meters
Correction	—36 meters
Total range correction for projectile weight and propellant temperature (—1) + (—36) = 37 or —40.	

** d. Determination of Quadrant Elevation.*

Range plus projectile weight and propellant temperature differences (10,470 + (—40))	10,430 meters
Elevation (use GFT with GFT setting)	364 mils
Site (+173/10,470; chg 3, TAG, GST)	+19 mils
QE shell HES (364 + (+19))	383 mils
QE ballistic correction (ballistic correction table in tabular firing tables; use QE to the nearest listed value and the HOB above gun to the nearest meter.)	+10 mils
QE to be fired	393 mils

** e. Determination of Fuze Setting.*

Angle of site (+173/10,470) C and D scales, GST	+17 mils
Comp site (+19 — (+17))	+2 mils
Elevation plus comp site (364 + (+2))	366 mils
Fuze setting for elevation plus comp site (366)	31.6
Total fuze correction	—0.4
Ballistic fuze correction (ballistic correction table in tabular firing table, use nearest listed QE and the HOB above gun to the nearest 1 meter)	+0.5
Fuze setting to be fired (31.6 + (—0.4) + (+0.5))	31.7

f. Determination of Deflection To Be Fired.

Chart deflection	3,132 mils
Total deflection correction (deflection correction scale)	Left 5 mils
Deflection to be fired	3,137 mils

** g. Firing Data.*

Target	YX1101
Shell	Nuclear
Lot	WY
Charge	3
Deflection	3,137 mils
Fuze setting	31.6
QE	393 mils

30-12. Observer Adjustment

** a. General.* If the information necessary to employ either the met plus VE or the K-transfer technique is not available, an adjustment may be made with shell HES followed by fire for effect with shell NUC. The procedure will differ from the

normal HE adjustment in that the observer must conduct a simultaneous adjustment of deviation, range, and height of burst to the normal 20 meters. Deflection, elevation, site, 100/R, and fuze setting are determined in the same manner as for the HE projectile. The fuze setting is not determined by

using the elevation plus comp site method during the adjustment phase because the vertical interval will automatically correct for small errors during the adjustment.

★ *b. Initial Data.* For the first spotting round, an angle of site based on a vertical interval of 20 meters and the GT range must be computed and added to the site for the ground location in the same manner as for conventional time fire. When a subsequent height of burst correction is given by the observer, the computer uses the 100/R factor to determine the height of burst correction in mils which is applied to the previous site. For example, the observer's height of burst correction is UP 20 and 100/R is 29 mils. Twenty-nine is multiplied by .2 with the result of 5.8 or plus 6 mils as the height of burst correction. With a previous site of plus 8, the new site is plus 14 mils.

★ *c. Fire-for-Effect Data.*

(1) The chart data are determined in the same manner as in the adjustment phase. The observer's fire-for-effect request should place the burst over the target with a height of burst of 20 meters. The height above the target must be corrected by the difference between the height of the last round in the adjustment and the desired height above target for the nuclear round. If the observer requested LEFT 20, ADD 50, UP 5, FIRE FOR EFFECT and the desired height of burst above target for the nuclear round is +180 a height-of-burst correction of UP 165 must be applied. Since the observer requested UP 5 and he is striving for a 20-meter height-of-burst, then the last round must have been 15 meters ($20 - 5 = 15$) above the target. Subtracting the 15 meters already achieved from the desired 180 meters results in a height-of-burst correction of UP 165 meters. If the observer requests LEFT 20, ADD 50, FIRE FOR EFFECT and the desired height above target is +180 meters, the correction would be UP 160. Since the observer did not make a height-of-burst correction, the height of burst is correct (20 meters). A correction of UP 160 would be applied ($180 - 20 = 160$).

(2) The large height-of-burst correction requires the consideration of site (angle of site + comp site) instead of the 100/R value which is only angle of site. Also, the fuze setting must be corrected by the amount of comp site involved. This requires the GST computation of both site and angle

of site, using the height-of-burst correction and the fire-for-effect range. The site is included as the height-of-burst correction to the last site fired. The comp site is determined (site minus angle of site) and added to the elevation for the fire-for-effect range to determine the fuze setting. A range correction for the differences in projectile weight and in propellant temperature must be applied, if appropriate, before the elevation and the fuze setting are determined.

(3) The QE for the spotting round is the elevation corresponding to the chart range plus the range correction for propellant temperature (PT) and the projectile weight (PW), plus the site for the additional height above target, plus the last site fired.

(4) Ballistic corrections to QE and fuze setting are determined at the QE for the spotting round and the total height of burst above gun (sum of initial vertical interval, the observer's net height-of-burst corrections, and the desired height of burst above the target).

(5) The QE to be fired is the QE for the spotting round in (3) above plus the ballistic QE correction.

(6) The fire-for-effect deflection is the chart deflection to the final target pin location.

(7) The time to be fired is the fuze setting corresponding to the elevation plus comp site, plus the total fuze correction (if any), plus the ballistic correction (determined as in (4) above).

30-13. Example—Observer Adjustment Technique

a. Chart Data to Initial Location Requested by Observer (fig 30-3).

Range.....	3,460 meters
Deflection.....	3,289 mils
Altitude of the battery.....	318 meters
Map altitude of the target.....	336 meters
Desired height of burst above target.....	+180 meters
Projectile weight (HES and NUC).....	242 pounds
Propellant temperature (HES and NUC).....	70°F

b. Determination of Initial Data Using Charge

1. See figure 30-3 for initial data for charge 1.

c. Determination of Subsequent Data. See figure 30-3 for subsequent data.

d. Determination of Fire-for-Effect Data. See figure 30-3 for fire-for-effect data.

(1) *Determination of quadrant elevation.*

FDC COMPUTER'S RECORD																
For use of this form, see FM 6-40; the proponent agency is U.S. Continental Army Command.																
Battery B		Date 31 MAR		Time received 1420		Time completed 1450		Target number AZ---								
Call for fire 44, FM, GRID 41263795, DIR 4170, INF BN ASSEMBLY AREA, ADJUST FIRE Fire order: Unit(s) B Mf #1 ① Basis for corr USE GFT SH HES LOT XY Distr Shell NUC Lot WY Charge 1 Fuze Ti 1 rounds; spread Time --- Tgt no AZ---				Df corr 0		INITIAL FIRE COMMANDS										
				Deflection 3289		# 1 Adjust		Sp instr								
				Range 3460 EL 314		Shell HES		Lot XY								
				Site +6		Charge 1		Fuze Ti								
				20/R +6												
				326												
				100/R 29		20/R 6		△ FS		Df 3289		Time 15.2				
										QE 326		Ammo exp ①				
OBSERVER CORRECTIONS					SUBSEQUENT FIRE COMMANDS											
Shell, fz, mf	Dev	Range	Height	Sh, chg, fz, mf	Range	Chart df	Corr (0)	Piece df	FS Corr	Time	HOB Corr	Site (+12)	EL	QE	Ammo exp	
		L 30	+200	D 20		3430	3306	0			16.1	-6	+6	334	340	②
		R 20	-100	U 10		3540	3298	0			15.6	+3	+9	323	332	③
		L 10	-50	US, FE		3500	3297	0			15.7	+54	+63	319	382	
											+0.3			+10		
											16.0			392	①	
<u>HOB CORRECTION</u>					<u>QE BAL CORRECTION</u>											
+180 DESIRED HOB					+180 DESIRED HOB											
-(+15) ACHIEVED HOB(20-5)					+18 INITIAL VI											
+165					+(-5) NET HOB CORR											
+54 SITE(+165/3500)					+193 HOB ABOVE LEVEL POINT											
-(+48) ANGLE OF SITE(165/3500)					+10 BAL QE CORR(+193+380)											
+6 COMP SITE					+0.3 BAL FZ CORR(+193+380)											
319 ELEVATION																
325 ELEVATION PLUS COMP SITE																
15.7 FUZE SETTING FOR EL																
PLUS COMP SITE																
DATA FOR REPLOT																
Coordinates				Altitude				Fuze				Target number				
AMMUNITION																
Type																
Lot																
On hand																
Received																
Total																
Expended																
Remaining																

DA FORM 3622, 1 Aug 70

REPLACES DA FORM 6-16, 1 AUG 62, WHICH IS OBSOLETE.

Figure 30-3. FDC computers record.

Height of burst in relation to the target and the last round fired (20-5).	+ 15 meters.
Desired height of burst above target.	+ 180 meters.
Height-of-burst correction (180—15).	+ 165 meters.
Site correction (+ 165/3500; chg 1, TAG, GST).	+ 54 mils.
Entry range (3500 + (+52) not required because PT and PW corrections are not necessary in this problem.	3,552 meters.
Elevation for range 3500 (GFT)	319 mils.
Site (last site fired (+9) + site correction (+54)).	+ 63 mils.
QE for spotting round	382 mils.
Total target height above gun (desired HOB above (+180) + vertical interval (+18) + observer's net correction (—5)).	+ 193 meters.
QE ballistic correction (+ 193 HOB and 380 QE).	+ 10 mils.
QE to fire nuclear round	392 mils.

(2) *Determination of fuze setting.*

Angle of site for HOB correction (+ 165/3500; C and D scales, GST).	+ 48 mils.
Comp site for HOB correction (+ 54 — (+ 48)).	+ 6 mils.
Elevation + comp site (319 + 6)	325 mils.
Fuze setting for elevation plus comp site, (325).	15.7
Ballistic fuze correction (+ 193 HOB and 380 QE).	+ 0.3.
Fuze setting to fire (+ 15.7 + (+ 0.3)).	16.0.

(3) *Determination of deflection.*

Deflection (chart deflection to FFE location)	3297 mils
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(4) *Fire-for-effect data.*

Deflection	3,297 mils.
Fuze setting	16.0.
QE	392 mils.

Section II 155-MM HOWITZER—NUCLEAR DELIVERY

30-14. General

a. *Procedure.* This section describes the fire direction techniques for delivery of the 155-mm howitzer nuclear round. Nuclear delivery techniques for the 155-mm howitzer parallel standard gunnery procedures whenever possible; however, the lack of a ballistically matched spotting round requires modifications to normal procedures. Test firings have determined that corrections derived from a high-burst registration with projectile HE, M107, introduce errors when these corrections are applied to data for the nuclear round. The magnitude of these errors is comparable to errors introduced when the VE and fuze correction for the nuclear round are assumed to be zero. When the met correction technique is used, registration with HE rounds does not provide increased accuracy and all nonmeasurable conditions (VE and fuze correction) are assumed to be standard and corrections are computed only for those conditions which are reported in a met message and by the firing battery. In those cases in which survey or met

data are not available, an adjustment may be conducted on the target with HE projectiles armed with mechanical time fuzes. When the adjustment phase is completed, the ballistic corrections are added to the HE data and the nuclear round is fired in effect. If current met data are not available but a valid HE GFT setting exists, a K-transfer procedure can be used when weapon and target locations are known and the target is within transfer limits. The HE data to the target are computed, ballistic corrections are added, and the nuclear round is fired in effect.

b. *Nomenclature.* The 155-mm nuclear round consists of the XM454 projectile, the XM32E1 sequential timer, the T361 VT fuze, and the XM72 propellant.

c. *Preferred Technique.* The preferred technique for the delivery of nuclear rounds from a 155-mm howitzer is the met correction technique in which VE and fuze correction are assumed to be zero.

d. *Alternate Techniques.* If the information for the employment of the preferred technique is not available, the following techniques may be used:

(1) Adjustment with HE rounds and fire for effect with nuclear rounds.

(2) K-transfer (HE GFT setting).

30-15. Requirements for Delivery Techniques

The requirements for the use of the various delivery techniques for 155-mm nuclear rounds are as follows:

a. Met Correction Technique.

(1) Accurate survey data for the gun and target.

(2) Current met data.

b. *Observer Adjustment.* The observer must be in position to observe.

c. K-Transfer (HE GFT Setting).

(1) Valid GFT setting and deflection correction.

(2) Accurate target location.

(3) Target within transfer limits.

30-16. Accuracy

All data are determined to the same accuracy as that for standard gunnery procedures.

30-17. Selection of Delivery Technique

a. *Considerations in Selection of Delivery Technique.* Listed below are some of the considerations in the selection of a delivery technique. The S3 must evaluate all considerations in making his decision.

(1) Tactical situation.

(2) Commander's guidance.

(3) Desirability of surprise.

(4) Availability of met.

(5) Time available.

(6) Registration restrictions.

(7) Survey.

(8) Validity of GFT setting and deflection correction.

b. *Registrations.* It is anticipated that the unit will have adequate met support and will obtain a valid HE GFT setting and total deflection correction by registering or by computation. The S3 will then have three options ((1) through (3) below) for delivery of the nuclear round. The selection of the technique is based on the considerations listed in a above.

(1) Met corrections.

(2) Observer adjustment.

(3) K-transfer.

(a) Use registration data if still current.

(b) Reregister if data are not current.

c. *Accuracy of Techniques.* The accuracy of each technique is dependent on some of the considerations listed in a and b above. There are so many variables that one technique cannot be considered as the most accurate technique under all conditions. General guides are as follows:

(1) The met correction technique will probably be the most accurate method under most conditions. Even though a current met message and an HE deflection correction are available, the assumption that the VE and fuze correction are zero introduces some errors into the met correction technique. These errors are approximately the same as those which would occur if corrections obtained from registering with HE projectile, M3 or M3A1 propellant (charges 4 and 5), and fuze time were applied to nuclear data (charges 1 and 2). These errors are less than those which would occur if corrections obtained from registering with HE projectile and M4A1 or M4A2 propellant (charge 7) were applied to nuclear data (charge 3). The accuracy of this technique is dependent on the amount (unknown) by which the VE varies from standard, the validity of the met message, and the accuracy of target location.

* (2) The observer adjustment technique is required when a current met message is not available or when the battery or target location is unknown. The disadvantages are the time and HE ammunition consumed, the loss of surprise, the requirement for an observer to be in position, the inaccuracy of applying HE data to the nuclear round, and the inaccuracy of fire (normally a 100-meter bracket split).

* (3) The accuracy of the K-transfer technique using current registration data depends on the validity of applying HE data to the nuclear round. If the target is accurately located and in proximity to the registration point, accuracy should approximate that of the observer adjustment technique. In the fringe areas of the transfer limits or outside the transfer limits, the accuracy can be expected to decrease. The principal advantage is the capability of delivery nuclear fires without adjust-

ment and elimination of the requirement for a current met message and computation of corrections for the target.

d. Time Requirements. The time required to prepare fire commands to fire a nuclear round depends on the data available. If a current GFT setting is available, the K-transfer technique will be the fastest. The next most rapid solution is the met correction technique. The K-transfer technique will be the slowest if a registration must be fired, because of the time required to register. The observer adjustment technique is dependent on the speed of adjustment.

e. Ballistic Corrections. The 155-mm howitzer firing tables used for nuclear delivery are constructed for projectile, atomic, XM454. When the HE projectile, M107, is used in the observer adjustment technique or when an HE GFT setting is used to determine corrections, the deflection, fuze setting, and quadrant elevation for the HE projectile must be corrected by the amount of ballistic corrections determined from table O of the firing tables. The firing table is entered with the final QE for projectile HE.

30-18. Example—Met Correction Technique (fig. 30-4)

a. Weapon-Ammunition Data.

155-mm howitzer, M109	
Altitude of battery	273 meters
Latitude of battery	34°N
Laying information:	
Azimuth	5,700 mils
Deflection	3,200 mils
Propellant Temperature	54°F
Projectile weight	118.5 pounds
Charge	3

b. Chart Data.

Deflection to registration point	3,180 mils
Deflection to target	3,014 mils
Azimuth to target	5,886 mils
Range to target	11,440 meters
Altitude of target	342 meters
Height of burst above target	+25 meter

c. Data from Registration.

Adjusted deflection	3,176 mils
Met deflection correction	R6 mils
Total deflection correction	R4 mils
Position deflection correction	L2 mils

* d. Recent NATO Meteorological Message.

METB31	344983	260750	021982		
001409	984017	011312	984025	021115	968031
031217	959026	041422	942017	051527	920009

** e. Quadrant Elevation.* Add the entry range to the total range correction (fig. 30-4) to determine the corrected range. Determine the elevation plus comp site for the corrected entry range; and the angle of site to obtain the quadrant elevation.

Corrected entry range (11,460 + (+190))	11,650 meters
Elevation plus comp site for corrected entry range	406.4 mils
Angle of site	+8.4 mils
Quadrant elevation	414.8 or 415 mils

** f. Deflection.* Add the new met deflection correction and the position deflection correction at the registration point to the chart deflection.

Corrected deflection	3,017 mils
----------------------	------------

* g. Timer Setting.

Timer setting for 11,650 meters	35.1
Intermediate timer setting (35.1 + (-0.2))	34.9
Correction for timer temperature	0
Timer setting	34.9

* h. Fire-For Effect Data.

Deflection	3,017 mils
Timer setting	34.9
QE	415 mils

30-19. Example—Observer Adjustment Technique

a. Weapon-Ammunition Data.

155-mm howitzer, M109	
Laying information:	
Azimuth	800 mils
Deflection	3,200 mils
M107 charge	7
XM454 charge	3

b. Chart Data.

MET DATA CORRECTION SHEET (FM 6-40)									
BATTERY DATA					MET MESSAGE				
CHARGE	ADJ OE	CHART RG	LATITUDE	TYPE MESSAGE	OCTANT	AREA/UNIT			
3		11,440	30°N	METB 3	1	344983			
ALT OF BTRY (10 m)		270		DATE	TIME	ALT MDP	PRESSURE		
				26	0730	210	98.2		
ALT OF MDP		210		LINE NO.	WIND DIR	WIND SPEED	AIR TEMP	AIR DENSITY	
				04	1400	22	94.2	101.7	
BTRY ABOVE MDP (AN)		+ 60		A & B CORRECTION			0 0.1 0 0.6		
ALT OF TARGET (nearest meter)		342		CORRECTED VALUES			94.1 101.1		
HEIGHT OF BURST ABOVE TARGET		+ 25							
ALT OF BURST		367							
ALT OF BTRY (nearest meter)		273							
HEIGHT OF TARGET (burst) ABOVE GUN (M)		+ 94		COMP RG	CHART RG	ENTRY RG	11,500		
				+18	11,440	11,458			
WIND COMPONENTS AND DEFLECTION									
WHEN DIRECTION OF WIND IS LESS THAN DIR FIRE ADD		6800		Pos DF Corr L2					
DIRECTION OF WIND		1400		Met DF Corr L1					
		7800		Total DF Corr L3					
DIRECTION OF FIRE (5886)		5900		ROTATION CORR R 0.9					
CHART DIRECTION OF WIND		1900		DRIFT CORR 11.7					
CROSS WIND	WIND SPEED	22	* CORR	0.96	21	KNOTS	0.54	CROSS WIND CORR	11.3
RANGE WIND	WIND SPEED	22	* CORR	0.29	6	KNOTS	1.3	MET DEF CORR R	1.3 L1
MET RANGE CORRECTION									
	KNOWN VALUES	STANDARD VALUES	VARIATIONS FROM STANDARD	UNIT CORRECTIONS	PLUS	MINUS			
RANGE WIND	6	0	6	-11.0		66.0			
AIR TEMP	94.1	100%	5.9	+ 7.8	46.0				
AIR DENSITY	101.1	100%	1.1	+41.7	45.9				
PROJ WEIGHT	118.5	120.4	1.9	+10.0	19.0				
ROTATION	+23 x 0.87				20.0				
						130.9	66.0		
						66.0			
						64.9	+65		
COMPUTATION OF VE									
PROP TEMP	54°	VE		D +24.6	TOTAL RANGE CORRECTION				
	CHANGE TO MV FOR PROP TEMP	-5.0	M/S	I -24.1	MET RANGE CORRECTION	+65			
	AV	-5.0	M/S	MV UNIT CORRECTION +24.6	AV RANGE CORRECTION	+123			
					TOTAL RANGE CORRECTION	+188 +190			
T1 35 MET FUZE CORRECTION									
	VARIATION FROM STANDARD	UNIT CORRECTION	PLUS	MINUS					
AV	5.0	-0.046		0.230					
RANGE WIND	6	+0.006	0.036						
AIR TEMP	5.9	+0.005	0.030						
AIR DENSITY	1.1	-0.051		0.056					
PROJ WEIGHT	1.9	+0.002	0.004			TOTAL FUZE CORRECTION			
				0.070	0.286	MET FUZE CORRECTION	-0.2		
					0.070	FUZE CORRECTION			
					0.216	TOTAL FUZE CORRECTION			
MET FUZE CORR									
OLD FZ CORR * NEW FZ CORR * 2 = AVG FZ CORR									
TARGET NO.		BATTERY			DATE/TIME				

DA FORM 6-15

REPLACES EDITION OF 1 MAY 66, WHICH WILL BE USED.

* Figure 30-4. Met data correction sheet.

Deflection to target	3,327 mils
Range to target	8,780 meters
Site to target	+7 mils
100/R	12 mils
Desired height of burst (XM454)	+30 meters

c. Adjustment with Projectile M107, Fuze Time, for 20-Meter Height of Burst.

1	-400
2	+200
3	-100
4	Time +50
5	U10, FFE

d. Data Obtained from Round 5.

Projectile	M107
Fuze	M564
Deflection	3,324 mils
Time	23.1
QE	259 mils

e. Site Correction for 30-Meter Height of Burst for Projectile XM454.

$$+10(12/100) = +1 \text{ mil}$$

f. Corrected QE for Projectile M107.

$$259 + (+1) = 260 \text{ mils}$$

★ g. Corrections from Table O, FT 155-AJ-2.

Deflection	L2 mils
Timer setting	+1.2
QE	+25 mils

★ h. Fire-for-Effect Data for Projectile XM454.

Deflection	3,326 mils
Timer setting	24.3
QE	285 mils

30-20. Example—K-Transfer Technique

a. Weapon-Ammunition Data.

155-mm howitzer, M109

Laying information:

Azimuth	6,200 mils
Deflection	3,200 mils
XM454 charge	3

b. Chart Data.

Deflection to target	3,142 mils
Range to target	9,910 meters
Vertical interval	+47 meters
Desired height of burst	30 meters

★ c. GFT Setting and Total Deflection Correction.

GFT B: Chg 7, lot ZN, rg 10,420,
el 354, ti 30.8

Total deflection correction to target L4 mils

★ d. Data for Projectile M107.

Site	+9 mils
Deflection	3146 mils
Time	28.7
QE	335 mils

★ e. Corrections from Table O, FT 155-AJ-2.

Deflection	L2 mils
Timer setting	+1.0
QE	+20 mils

★ f. Fire-for Effect Data for Projectile XM454.

Deflection	3,148 mils
Timer setting	29.7
QE	355 mils

★ 30-21. VT Fuze

Firing the XM454 projectile with the variable time option provides a higher probability of achieving the desired height of burst than firing the projectile with the sequential timer option. When the variable-time option is used, the T361E2 VT fuze is armed by the XM32E1 sequential timer at a predetermined time. This predetermined time is established by subtracting a back-off time from the fuze setting computed for the XM32E1 fuze. The back-off time varies with the fuze temperature and table L of the XM454 firing tables lists the value to be subtracted from the computed time to determine the time to set on the XM32E1 fuze.

CHAPTER 31

AERIAL PHOTOGRAPHS

Section I. INTRODUCTION

31-1. General

This chapter provides the information required by field artillery units to plan for, request, and use aerial photographs. Other manuals containing pertinent information on the subject will be referred to by number. Only the aspects of aerial photographs directly related to artillery gunnery and not adequately covered elsewhere will be covered in detail in this chapter.

31-2. Planning

Factors involved in a unit's plan for aerial photographs are as follows:

a. Use. The purpose for which aerial photographs are required must be determined. The purpose will govern the type of photographs (FM 21-26), the scale desired, and the number of prints required.

b. Area To Be Covered. The area in which the unit requires photographic coverage must be determined.

c. Terrain Features. Prominent terrain features suitable for use as control points in the area to be photographed must be considered.

d. Survey. The possible need for expansion of existing survey for additional ground control must be considered.

31-3. Requesting Aerial Photographs

Requests for aerial photographs are normally routed through organic intelligence channels (FM 11-40).

31-4. Use of Aerial Photographs

Aerial photographs are used by field artillery for—

a. Target Acquisition. A study of aerial photographs can disclose recent enemy construction, digging, and movement (tracks and trails) and other enemy activity not discernible to other available observation agencies. Targets can be identified

on aerial photographs by their size and shape and by shadows and tones. The locations of targets can be transposed to maps and firing charts by restitution (para 31-10—31-16).

b. Reconnaissance. Aerial photographs can provide recent information on the condition of roads, bridges, streams, and other terrain features, and manmade objects. This information is an aid to map and visual reconnaissance.

c. Firing Chart. Vertical photographs (photomaps or mosaics) may be used as firing charts. When a map or grid sheet is used as a firing chart, aerial photographs are used to supplement the chart by providing additional horizontal locations.

31-5. Determining the Scale of Vertical Photographs

a. The determination of the scale of vertical photographs is presented in FM 21-26 and TM 30-245.

b. Information pertaining to the data printed on the margins of photographs is presented in TM 30-245.

31-6. Converting Photographic and True Measurements

a. Setting Relationship on Military Slide Rule. Photographic measurements may be converted to true distance (and true to photographic) by use of a military slide rule or GST by setting the photo distance (a number of units obtained with any convenient plotting scale) on the C scale of the slide rule directly over the true ground distance (meters) on the D scale. Once this setting has been obtained, any photographic measurement with the same plotting scale from the photograph can then be converted to true ground distance by moving the hairline to the photographic measurement on the C scale and reading the true ground distance under the hairline on the D scale.

b. Example. The true ground distance between

two points identified on a photograph has been determined to be 1,500 meters. A plotting scale is used to measure the distance between the two points on the photograph as 1,800 units. This photo distance (1800) on the C scale is set over the true ground distance (1500) on the D scale. A photographic measurement of 2,100 units is converted to a true ground distance by moving the hairline to 2100 on the C scale and reading the true ground distance (1750) directly below it on the D scale (fig. 31-1).

c. *Computing Relationship.* Photographic measurements may be converted to true distance (and true to photographic) by the use of the photo-ground relation. If the true (ground) distance between two points, A and B, which appear on a photograph is known, the distance measured (using any convenient units) on the photograph from A to B divided by the ground distance from A to B is the photo-ground relation and is expressed as a ratio as follows:

$$\frac{\text{AB photo (units)}}{\text{AB ground (meters)}}$$

The relation of the distance between any other two points on the photograph, C and D, to the ground distance between the same two points is the same ratio as for A and B; i.e.,

$$\frac{\text{AB photo (units)}}{\text{AB ground (meters)}} = \frac{\text{CD photo (units)}}{\text{CD ground (meters)}}$$

Therefore, if the photo distance from C to D is measured, the ground distance from C to D can be computed by transposing the previous equation to the following:

$$\text{CD ground (meters)} = \frac{\text{AB ground (meters)}}{\text{AB photo (units)}} \times \text{CD photo (units)}.$$

For example, the measured distance between two points on the ground is 1,500 meters, and the scaled distance between the same two points on the photograph is 1,800 units. A photographic measurement of 2,100 units is converted to true ground distance by using the following equation:

$$\frac{1800}{1500} = \frac{2100}{X}; X = \frac{(2100)(1500)}{1800} = 1,750 \text{ meters, the true ground distance.}$$

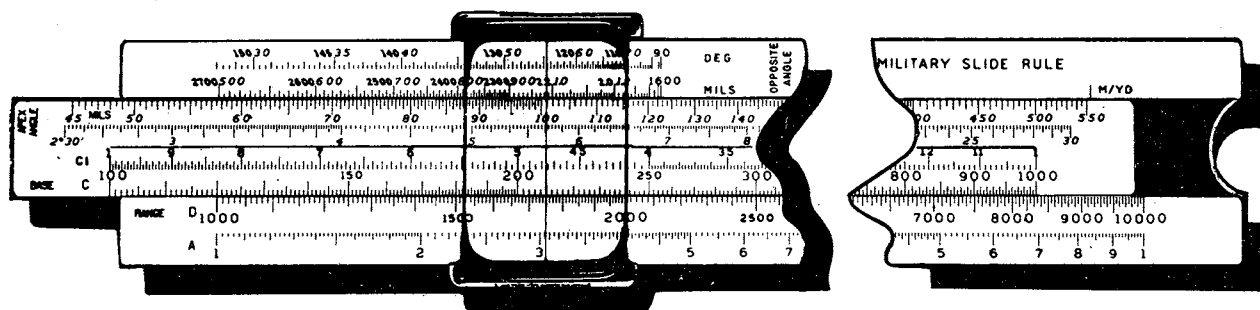


Figure 31-1. Method of using military slide rule for conversion of photographic measurements to true ground distance

Section II. DISTORTION IN AERIAL PHOTOGRAPHS

31-7. General

An aerial photograph of absolutely level ground taken by a camera with its axis truly vertical would result in a picture in which the relative location of points on the picture would be the same as on the ground or a map (fig. 31-2). However, the vertical photograph is subject to distortion of detail. This distortion is due mainly to tilt of the camera and to altitude differences of the terrain photographed.

31-8. Tilt

If the camera is not level at the instant the photograph is taken, the scale of the photograph will not be uniform. In figure 31-3, it is evident that a horizontal line of a certain length appearing on a photograph near X will appear longer than a line of the same length appearing on the same photograph near Y, since X is nearer the camera than Y. When the tilt in a photograph is small, the resulting errors are negligible for artillery use.

In a series of overlapping photographs taken on a single flight, excessive tilt of the camera in taking one of the photographs is apparent if the center of that photograph is materially off the line of centers established by other photographs. If tilt is great enough to distort a vertical photograph, that photograph cannot be used for restitution of points onto a firing chart. Normally, photographs taken with excessive tilt are not sent to using units, but, if an artillery unit does receive such photographs, corrected prints with the effect of tilt removed should be requested. Artillery units are not equipped to remove the effect of tilt from photographs. Tilt is discussed in more detail in TM 5-230.

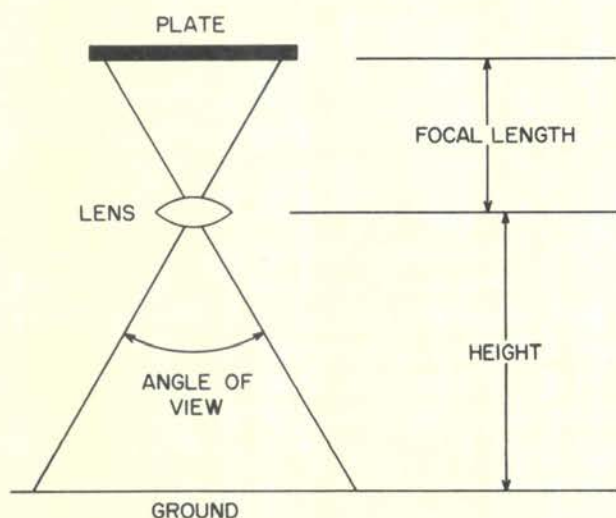


Figure 31-2. Photographic-ground relationship of a true vertical photograph

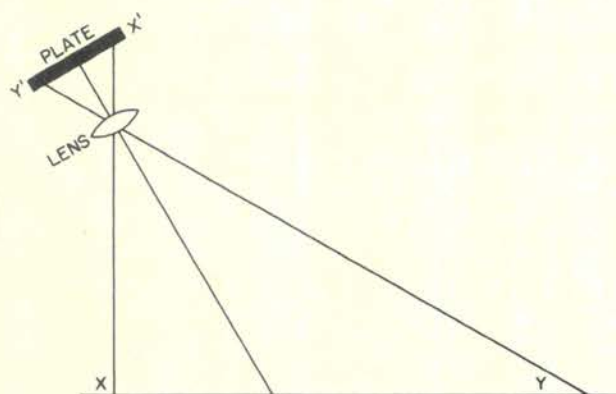


Figure 31-3. Effect of tilt

31-9. Relief

a. General. The other important source of error in vertical photographs is relief. A point at a higher altitude than the datum plane appears farther from the photo center than it should. Considering figure 31-4 as any vertical section through the axis of the lens, Z will be recorded in its true position, the center of the photograph, regardless of its altitude. With reference to a horizontal datum plane (line MN), an object (x) at a greater altitude will appear to be farther from the photo center than it actually is (X'); an object at a lower altitude will appear closer (Y will record as Y'). These displacements are radial from or toward the plumb point (point directly beneath the camera lens at the instant the photograph is taken—also referred to as nadir or ground). If the tilt is small, the plumb point and the center of the photograph can be considered to be the same.

b. Effect of Relief Displacement on Direction and Scale. The effect of relief is the displacement of images radially from or toward the center of the photograph. Considering figure 31-5, the points X and Y are on the higher ground and the point Z is on lower ground than the center of the photograph (P). In the figure, X, Y, and Z represent the true locations of these points, whereas X', Y', and Z' represent the photographic locations. The lines X'Z' and X'Y' are not true direction lines, whereas PX', PY', and PZ' are true and Y'Z' is approximately true. Therefore, the directions of lines passing through or near the center of an average vertical photograph are substantially true. However, lines passing well away from the center

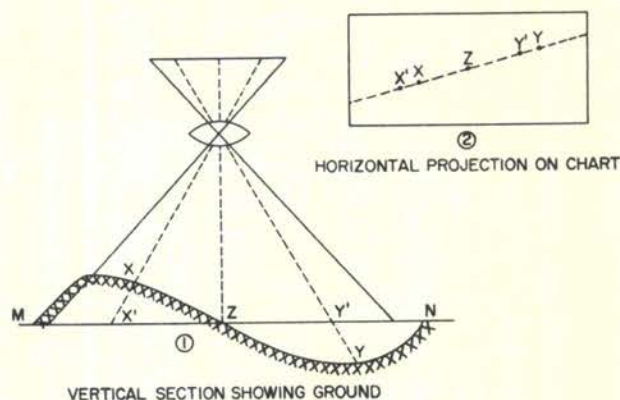


Figure 31-4. Displacement due to relief of ground

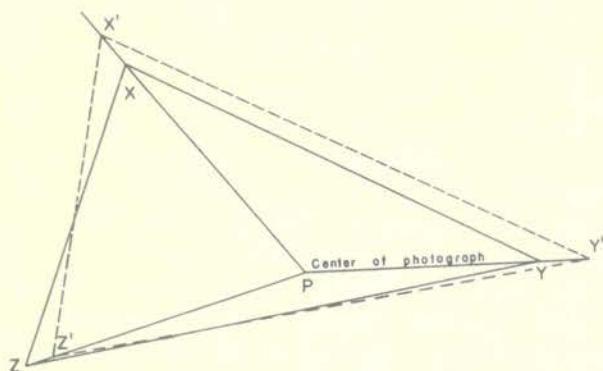


Figure 31-5. Effect of relief displacement on direction and scale

and joining points of different altitudes the images of which lie in the outer field of the photograph may show excessive errors in direction when relief is considerable. If the altitude from which the photograph was taken is known, the error may be corrected by a replot of the points to place them on the same datum plane.

c. Determination of Relief Correction. The amount of distortion (fig. 31-6), due to relief, can be found by solving the proportion $\frac{d}{D} = \frac{h}{H}$; d is the

displacement correction in meters (photo distance) radially toward (from) the center of the photograph, h is the height of ground above (below) the horizontal datum plane, D is the distance in meters (photo distance) from the center of the photograph to the point to be corrected, and H is the height of the camera lens above the horizontal datum plane. D may be measured with a 1:25,000 scale or with any other convenient scale. The resulting value of d will be expressed in the same units as D . Usually, the altitude of the center of the target area is assigned arbitrarily as the horizontal datum plane and is used as the basis for distortion corrections.

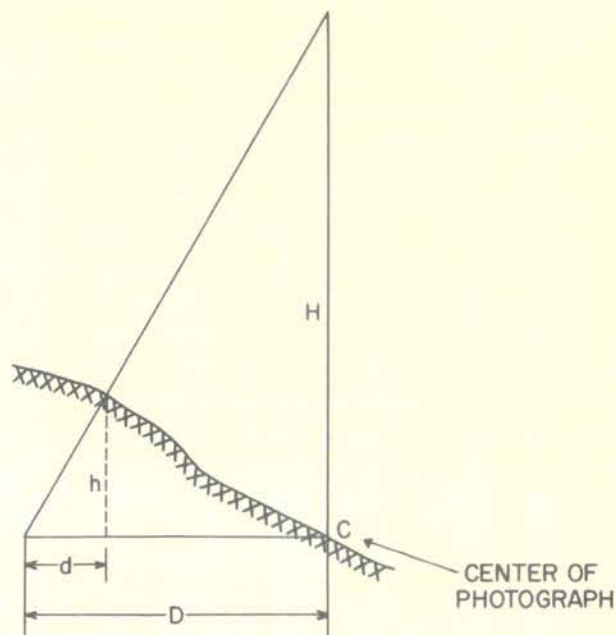


Figure 31-6. Determination of relief correction

d. Example of Correction for Relief Distortion. An aerial photograph taken at an altitude of 28,000 feet above sea level is to be used to determine the relative location of points on the firing chart. By survey, point X has been determined to be 180 feet above the registration point (①, fig. 31-7). The selected datum plane, based on the approximate altitude of the registration point, is 3,000 feet above sea level. Therefore, the height of the camera lens is 25,000 above the datum plane. The distance from point X to the center of the photograph is scaled as 4,000 meters. Point X will be plotted 29 meters ($\frac{d}{4000} = \frac{180}{25000} = 28.8$) along a radial line toward the center of the photograph from its photographic location (②, fig. 31-7).

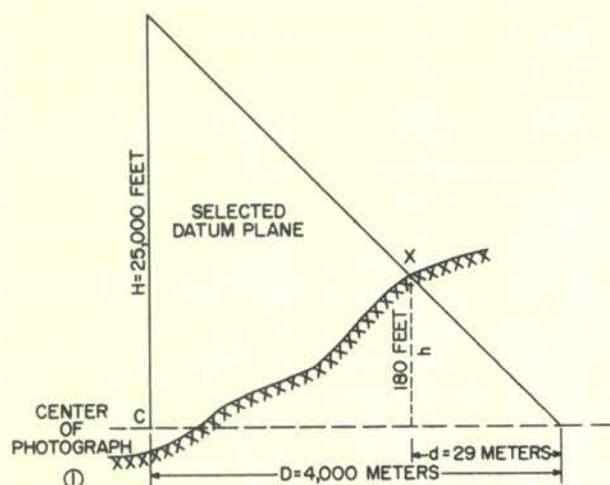


Figure 31-7. Example of correction for relief distortion

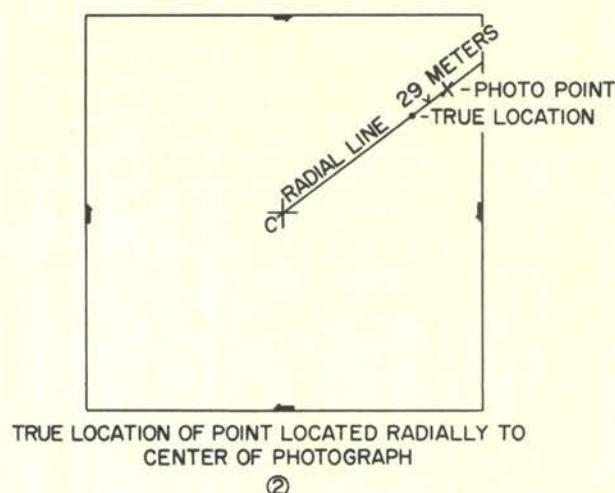


Figure 31-7—Continued

Section III. RESTITUTION

31-10. General

a. Restitution is the process of transferring points from an aerial photograph to a chart, from one photograph to another photograph, or from a chart to a photograph. Restitution may require the use of one or more photographs, depending on the method used.

b. The most accurate method of restitution is the radial line method (para 31-11), which requires the use of overlapping vertical photographs.

c. A single vertical photograph is used whenever the target does not appear on overlapping vertical photographs. There are four methods of restitution which involve the use of single vertical photographs only. These methods are listed below in order of accuracy and are discussed in paragraphs 31-12 through 31-15.

- (1) Alternate polar plot.
- (2) Polar plot.
- (3) Proportional dividers.
- (4) Tracing paper resection.

d. In the restitution procedures described in this chapter, critical points (photo centers, restitution points, targets, etc.) may be pricked through to a piece of overlay paper; the overlay paper may then be used in lieu of the photograph. The procedure will preclude having to draw any lines on the photograph except those lines necessary to locate the photo center.

31-11. Radial Line Method

For practical purposes, the combined effects of relief and tilt in photographs taken with a slightly tilted camera are assumed to cause displacements along radial lines passing through the centers of the photographs. This assumption is used in the radial line method of restitution to accurately determine the map position of a point appearing in the overlap of two aerial photographs taken at different camera positions. This is one method of restitution that will correct for both tilt and relief; however, if the tilt is greater than 3° or if the point sought falls on or near the line joining the centers of the two photographs, the method is not accurate because a good angle of intersection is difficult to obtain. The following procedure is used to restitute a target which appears on two overlapping vertical photographs:

a. Vertical Photographs:

- (1) Mark the photo center of each photograph. The photo center is the geometric center of the photograph and is determined by the intersection of lines through the corners of the photograph or through the fiducial marks along the edges of the photograph (①, fig. 31-8).
- (2) Identify on each photograph the three control points the chart locations of which are known. A different set of points may be selected for each photograph, or the

same points may be used. The points selected should be well out from the center of each photograph and widely distributed. Draw radial lines or rays from the center (C) of each photograph to the photographic locations of the control points (XYZ) (②, fig. 31-8).

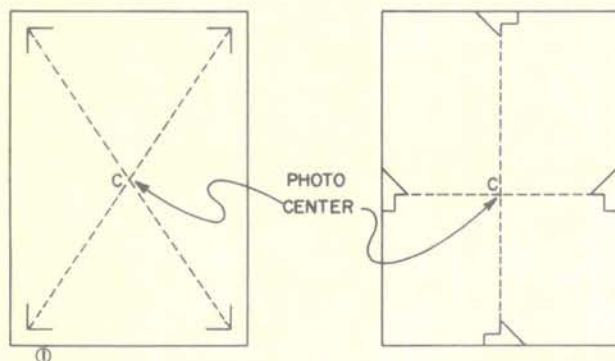


Figure 31-8. Radial line restitution

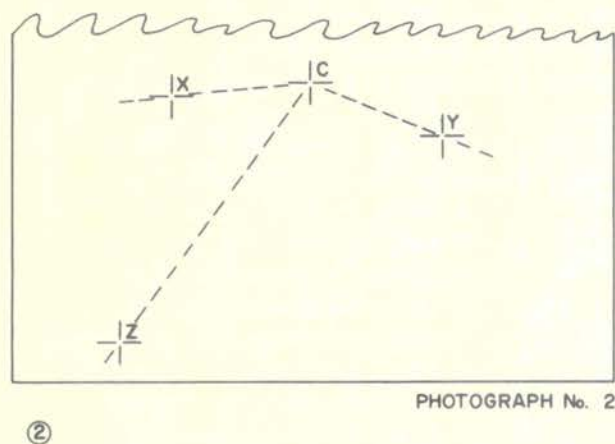
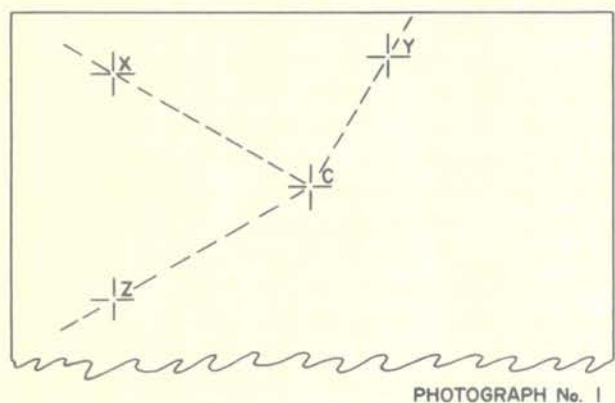


Figure 31-8—Continued

- (3) Place tracing paper over the firing chart and prick the chart locations of the control points on the tracing paper (③, fig. 31-8).
- (4) Place the prepared tracing paper over one photograph so that the rays on the photograph pass through the corresponding control points on the tracing paper (④, fig. 31-8).
- (5) Draw a ray on the tracing paper from the center of photograph 1 through the target to be restituted (T) (⑤, fig. 31-8).
- (6) Repeat the steps in (4) and (5) above on photograph 2, using the same tracing paper (⑥, fig. 31-8). The two photo centers and the ray from each photo center

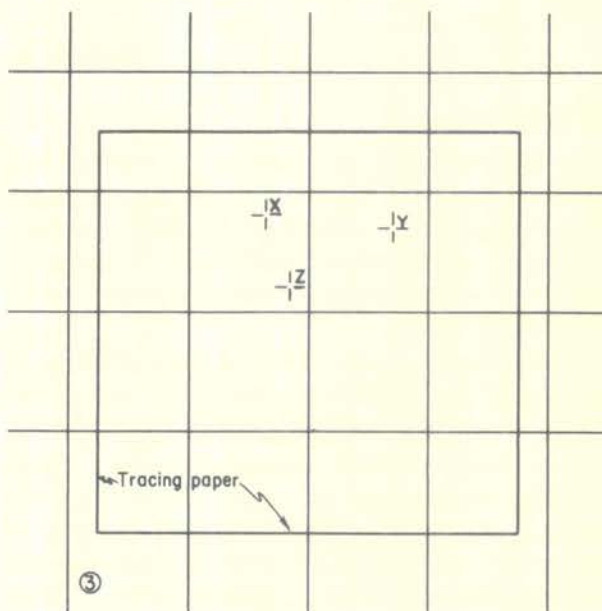


Figure 31-8—Continued

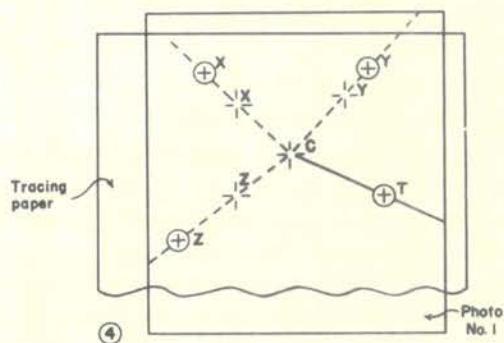


Figure 31-8—Continued

to T now appear on the tracing paper. Intersection of the rays through T gives the tracing paper location of the target to be restituted.

- (7) Orient the tracing paper over the chart (control point over control point) and prick through the intersection of lines, thus transferring the target to the chart (⑥, fig. 31-8).

b. Alternate Method. Another acceptable procedure for radial line restitution is one using two pieces of tracing paper, one with each photograph. The procedure for the alternate polar plot method (para 31-12) is followed until both pieces of tracing paper are correctly oriented over the chart, and then the intersection of the two photo center-target

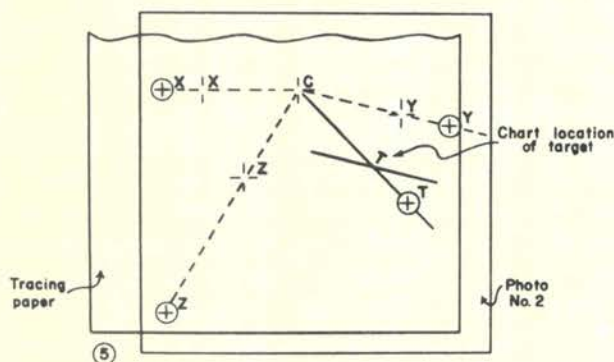


Figure 31-8—Continued

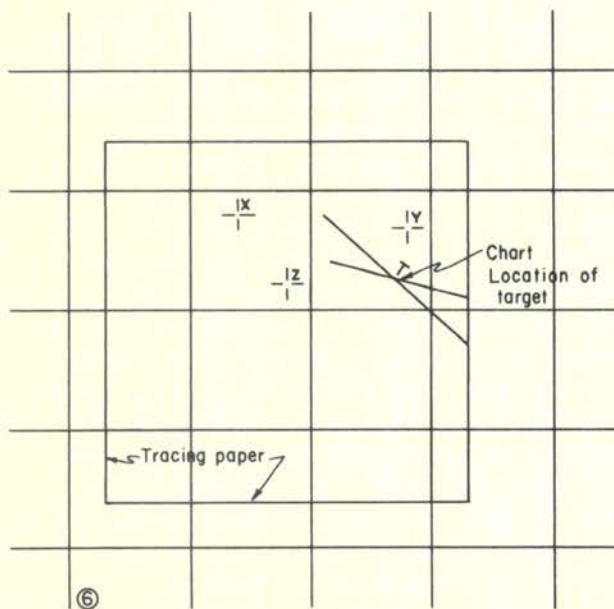


Figure 31-8—Continued

lines (one on each piece of tracing paper) is pricked through to the chart.

31-12. Alternate Polar Plot

The most accurate method of restitution from a single vertical photograph is the alternate polar plot method. This method partially eliminates errors due to distortion by using only radial lines from the photo center as bases for polar plotting. The procedure for the alternate polar plot method of restitution is as follows:

a. Identify on the photograph at least three points the chart locations of which are known and determine and mark the photo center. Draw radial lines on the photograph from the photo center C to the three known points (XYZ) and the target (①, fig. 31-9).

b. Make an overlay from the photograph and mark the photo center. Draw radial lines from the center through the three points (XYZ) and the target (②, fig. 31-9).

c. Place the overlay over the chart and move the overlay until the three rays pass through the control points on the chart (③, fig. 31-9).

d. To transfer a target to the firing chart, convert the photo distance to chart distance (para 31-6) and plot the chart distance on the ray drawn on the tracing paper from the photo center to the target and pinprick through the overlay paper (③, fig. 31-9).

31-13. Polar Plot

Another method of restitution from a single vertical photograph is the polar plot method.

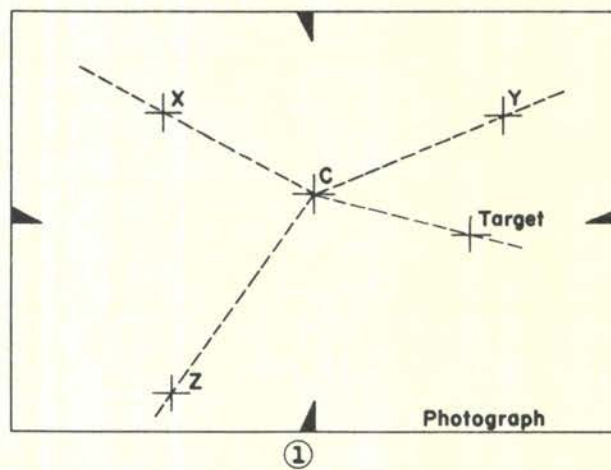


Figure 31-9. Alternate polar plot restitution

Since the angles used are not radial, inaccuracies from relief and tilt may be introduced. The procedure for the polar plot method of restitution, which is illustrated in figure 31-10, is as follows:

a. Identify on the photograph two or more well-separated points (A and B), the chart locations of which are known, and draw a line between these two points on both the photograph and the chart. These points should be at about the same altitude to reduce errors of relief and tilt, and the line established should pass close to the center of the photograph.

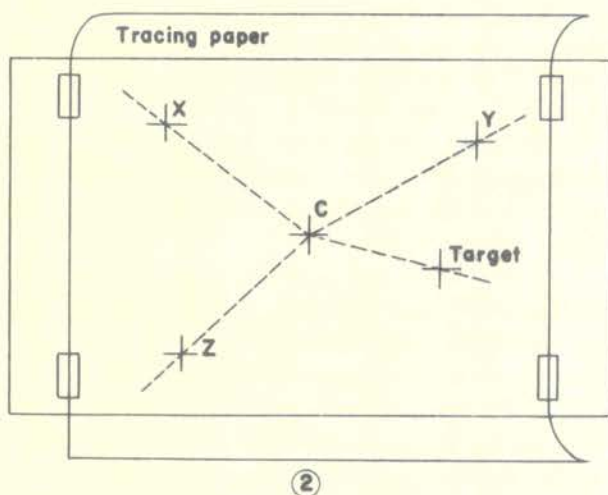


Figure 31-9—Continued

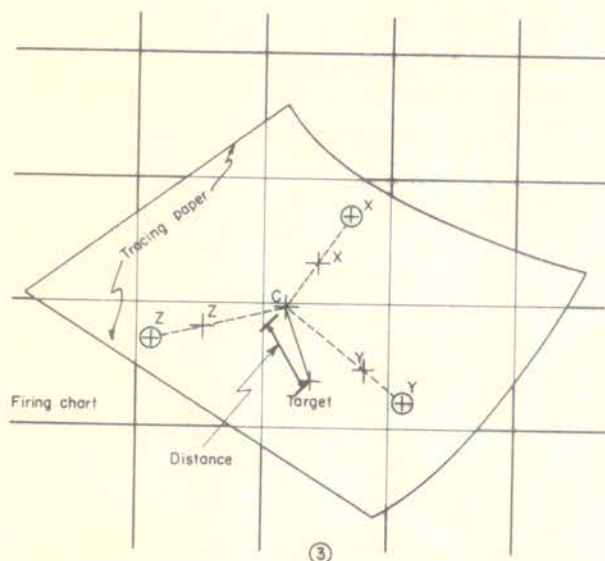


Figure 31-9—Continued

b. Extend the line of the photograph so that shifts and distances can be measured from either of the points with an angle-measuring device (protractor, range-deflection protractor, or GFT fan).

c. To compensate for the difference in scale between the photograph and the chart, measure the photograph and chart distances and set up a relationship between the two on a slide rule (para 31-6). In the example shown in figure 31-10, photo distance (4,000 meters) is placed on the C scale over the chart distance (5,200 meters) on the D scale.

d. To restitute a point (T) from the photograph to the chart, measure the angular shift from the known line and the distance from whichever known point will give the smallest angle and the longest distance. In this case illustrated in figure 31-10, the measurement was made from point B, and the results were an angular shift of 405 mils right of line BA and a photo distance of 3,980 meters.

e. Convert the photo distance to chart distance by using the relationship set up on the slide rule and the procedure described in paragraph 31-6. Move the hairline to the photo distance of 3,980 meters on the C scale, and read the chart distance of 5,170 meters directly below it on the D scale.

f. Plot the desired point T on the chart by using the measured shift of 405 mils right of line BA and the chart distance of 5,170 meters from point B.

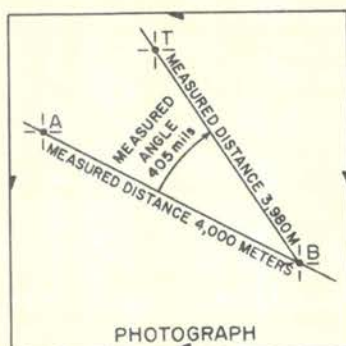
31-14. Proportional Dividers

The most rapid method of restitution is the proportional dividers method (fig. 31-11). The proportional dividers consist of two legs, each pointed at both ends, which are held together by means of a central pivot. When the legs are opened in the form of an X, either end of the instrument forms a pair of ordinary dividers. The position of the pivot along the legs can be varied to produce any desired ratio. Once the pivot of the dividers is set to the proper photograph-chart ratio, all points on any particular photograph may be restituted to the chart without disturbing the adjustment of the pivot. With the pivot at a fixed setting, distances are taken off the photograph with one end of the proportional dividers and laid off on the chart with the other end. These photo distances are subject to errors of tilt and relief. The follow-

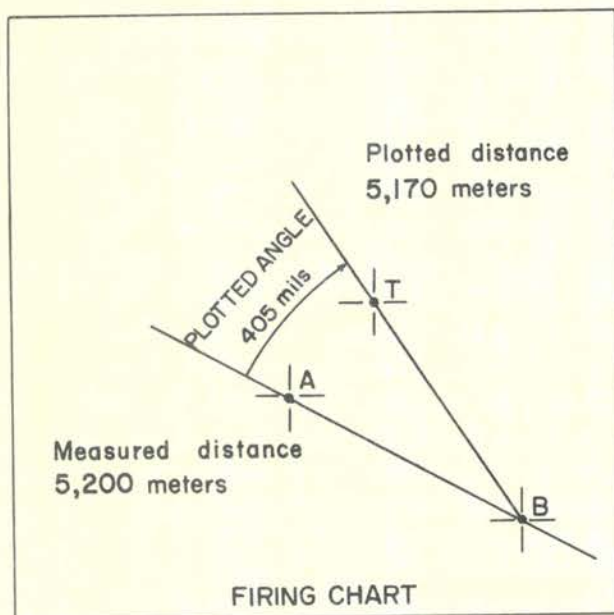
ing procedure is used to restitute points from a photograph to a chart:

a. Select restitution points which appear both on the photograph and the chart. In figure 31-11, the two points selected are the bridge and the fence corner.

b. By trial and error, adjust the pivot so that the points on the chart end of the dividers match the two restitution points on the chart when the points on the photograph end of the dividers match the two restitution points on the photograph.



①



②

Figure 31-10. Polar plot restitution

c. Using the photograph ends of the dividers (①, fig. 31-11), lay off the distance from the first restitution point to the point to be located. Without disturbing the adjustment, reverse the dividers and strike an arc on the chart from the first restitution point in the direction of the point to be located (②, fig. 31-11).

d. Repeat the procedure for the second restitution point. The location of the point on the chart is at the intersection of the two arcs drawn. If a third restitution point is available, draw another arc to give a check on the location determined from the first two.

31-15. Tracing Paper Resection

a. Points within a limited area appearing on a vertical photograph may be plotted roughly on a map or firing chart by the use of the tracing paper resection method of restitution.

b. To locate a point (P) (fig. 31-12), identify on the photograph at least three points (preferably five) that appear on the map or firing chart. Mark on a sheet of tracing paper the photographed position of these points and the point to be located.

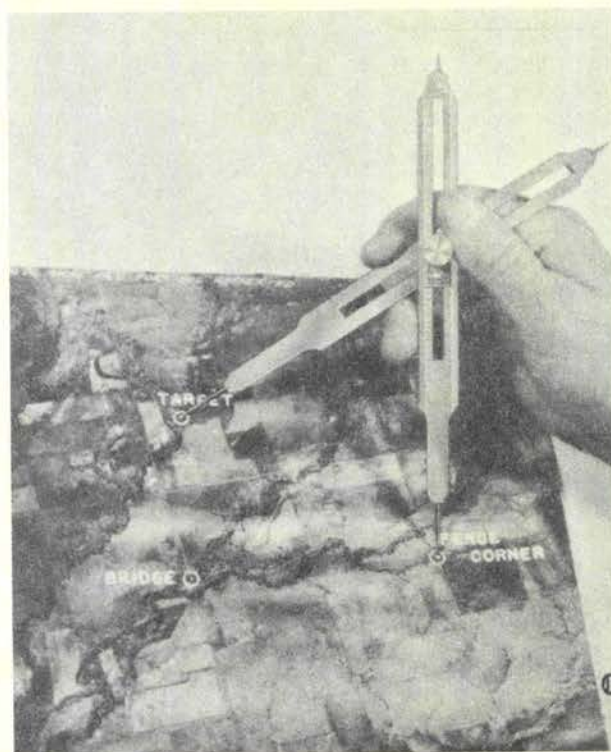


Figure 31-11. Restitution with proportional dividers

This is accomplished best by tacking the photograph over the tracing paper and pricking a pin through each point. On the tracing paper, draw rays from the point (P) to each of the known points (a, b, c, d, and e). Place the tracing paper on the map or chart so that the ray to each of the known points passes through the map or chart location of the corresponding point. The point (P), represented by the intersection of rays, is

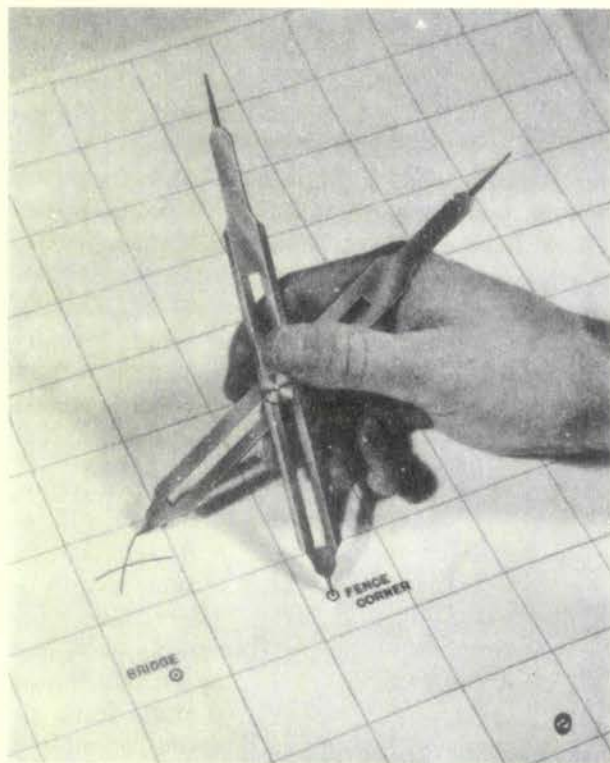


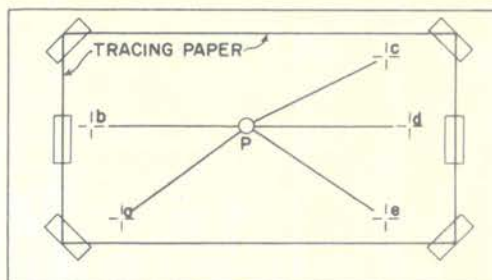
Figure 31-11—Continued

31-16. Vertical Control

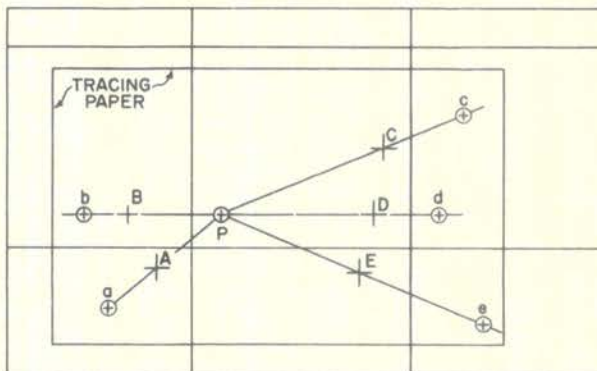
Normal methods of restitution do not include adequate means of determining vertical control. Use of a stereoscope may aid in determination of relative heights. High obliques, when gridded, can be used to supplement vertical control. If a map is available and points can be identified on both

now in its relative position to the known points; prick its position onto the map.

c. The tracing paper resection method is subject to errors of tilt and relief. The error of location can sometimes be reduced by selecting more than the minimum of three known points. Accuracy can be improved by selecting restitution points that are widely separated and that are near the altitude of the mean datum plane.



① PHOTOGRAPH



② TRACING PAPER OVERLAY

Figure 31-12. Tracing paper resection

the map and the photograph, vertical control is relatively simple. A pantograph (TM 5-230) can be used, if available, to transcribe contour lines from a map to a vertical photograph. Survey can also be used to establish vertical control, provided points are on terrain which is accessible, or visible to the survey party.

Section IV. OBLIQUE PHOTOGRAPHS

31-17. General

An oblique photograph is a photograph taken with the axis of the camera intentionally tilted from the vertical position. An oblique photograph

which shows the horizon is a high oblique; and an oblique photograph which does not show the horizon is a low oblique.

31-18. Characteristics

The primary characteristics of an oblique photograph are as follows:

- a. An oblique photograph may be taken from either an air or a ground observation post.
- b. A special camera is not necessary for taking an oblique photograph.
- c. Relief is more readily recognizable on an oblique photograph than on a vertical photograph.
- d. An oblique photograph is limited by its size and perspective to a useful depth of about 10,000 meters.

31-19. Uses

Oblique photographs are used for the following purposes:

a. *Reconnaissance.* The use of the oblique photographs to supplement visual reconnaissance enables a commander to more nearly see the terrain as it appears to an observer in a frontline position.

b. *Briefing.* Oblique photographs are used to brief ground and air observers and to designate objectives, phase lines, boundaries between units, zones of fire, zones of observation, and observation posts.

c. *Terrain Sketches.* Observers can use oblique photographs as terrain sketches. When a copy of the photograph is available to the fire direction center, it facilitates the exchange of battlefield information and enables the S3 and S2 to see the terrain as the observer sees it.

31-20. Mil-Gridded Oblique Photographs

a. A mil-gridded oblique photograph (fig. 31-13) is made by the Air Force by contact printing the negative through a transparent mil grid. A mil-gridded oblique photograph is used in conjunction with a firing chart to determine the horizontal and the vertical locations of points (fig. 31-14). A horizontal location of a point obtained from a gridded oblique photograph is not as accurate as that obtained from a vertical photograph. Therefore, an oblique photograph should not be used to determine a horizontal location when a vertical photograph is available. A gridded oblique photograph, however, may be used to good advantage in conjunction with a firing chart for the purpose of determining altitude.

b. The following terms are used in conjunction with the mil-gridded oblique photographs:

- (1) *Plumb point*—The point on the ground vertically beneath the perspective center of the camera lens.
- (2) *Centerline*—The map projection of the vertical plane that contains the axis of the camera at the instant the photograph was taken. On the photograph, the centerline appears as the zero line from which right and left angular measurements are taken. On the chart, the centerline appears as the direction line from which the right and left angular measurements are plotted.

31-21. Horizontal Locations

a. *Orientation of Photographs.* An oblique photograph is oriented by determining the chart location of the plumb point and the chart direction of the centerline.

- (1) *Location of plumb point.* The tracing paper method of resection can be used to determine the chart location of the plumb point. The chart locations of three or more ground control points appearing on the photograph are necessary. These chart locations may be determined by survey or may be taken from a map or a vertical photograph. The relative locations of the ground control points on the observed firing chart may be determined by firing. The horizontal angle from the centerline to each ground control point is read on the mil grid and plotted on the tracing paper with an angle-measuring device. The tracing paper is then placed over the chart in a position so that the ray toward each control point passes through the chart location of the same point. The plumb point is pricked through to the chart.
- (2) *Location of centerline.* When the tracing paper is in the same position as that in (1) above, any convenient point on the centerline can be pricked through to the chart.

Note. Each plumb point and centerline must be labeled with its photograph number; centerlines are marked with identifying arrows.

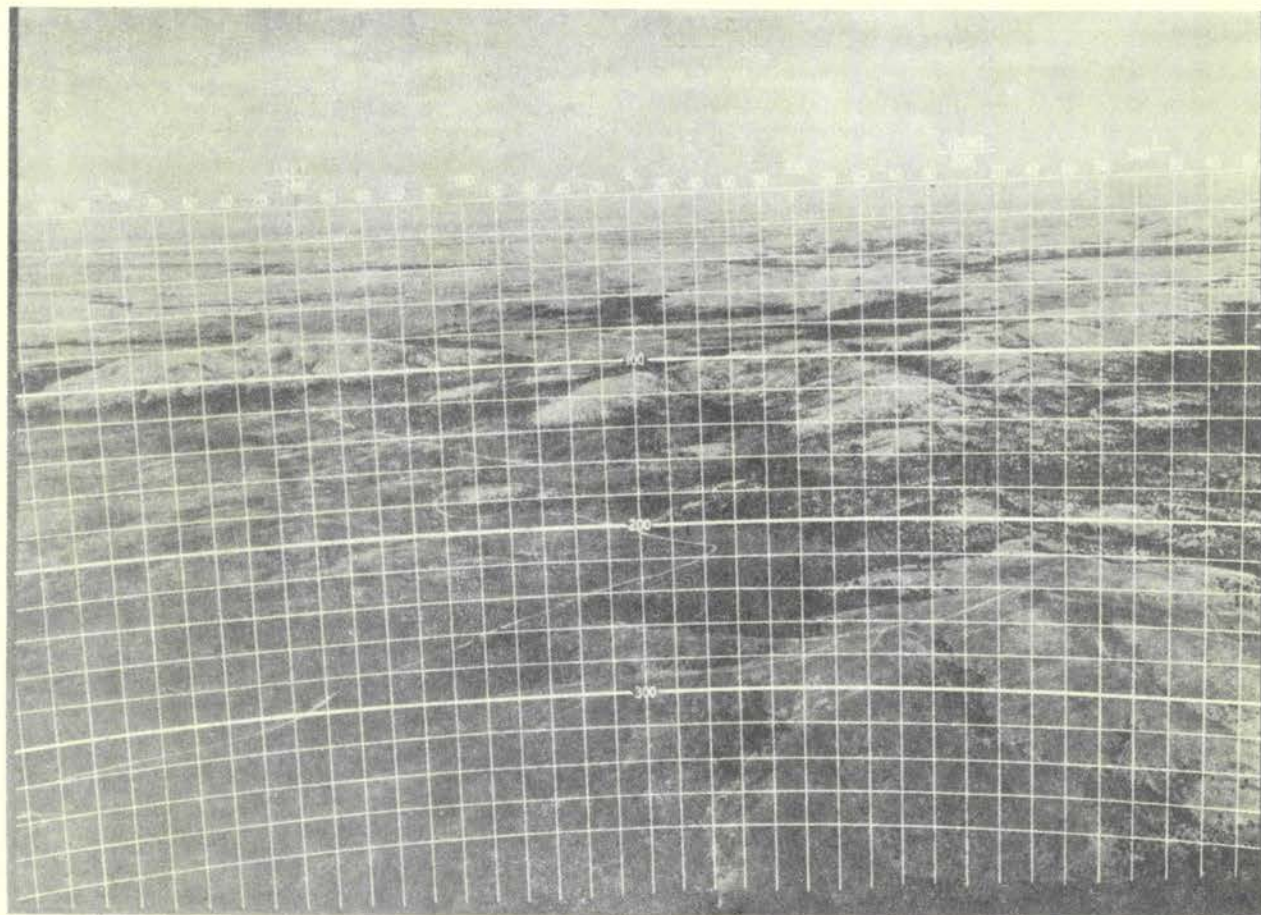


Figure 31-13. Mil-gridded oblique photograph

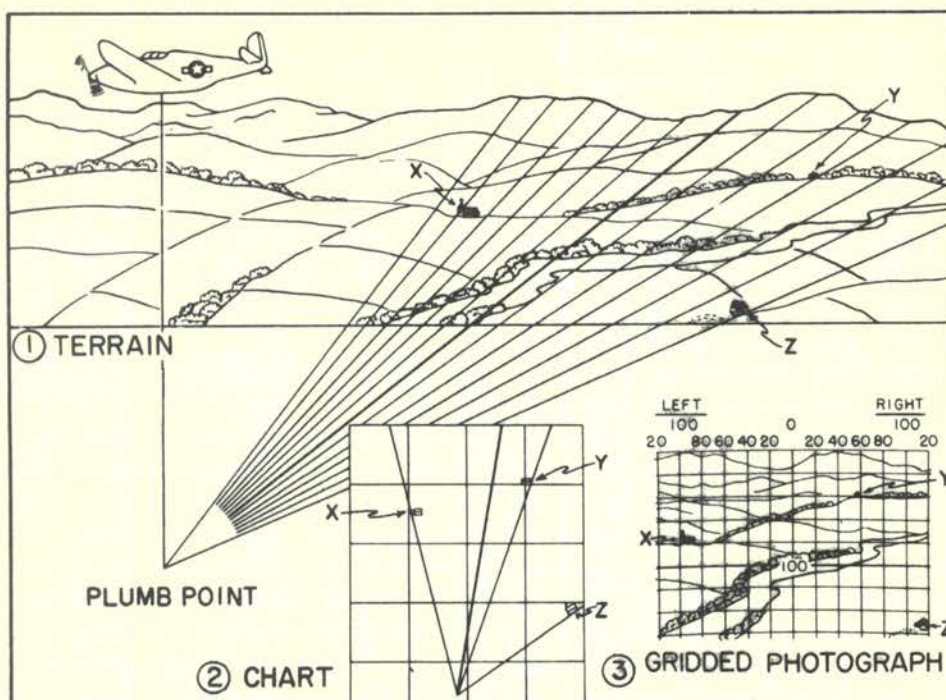


Figure 31-14. Mil-gridded oblique photograph used in conjunction with firing chart

b. Transposition of Points from Oblique Photographs to Charts.

- (1) *Point designation.* Oblique photograph references include a photograph number and horizontal and vertical angles; for example, "Photo 58, L156042. The photograph number (58) designates the photograph from which the reading was taken. The letter "L" or "R" indicates a reading left or right of the centerline. The first three figures (156) represent the horizontal angle from the centerline. The last three figures (042) represent the vertical angle from the 0 or level line.
- (2) *Plotting the point.* A point is located from an oblique photograph by plotting the intersection of two or more lines of sight.

Example: The following call for fire has been received: FM, BATTALION PHOTO 59, R210118, INFANTRY PLATOON WITH HEAVY WEAPONS, FIRE FOR EFFECT. Fire direction personnel identified the same point on photograph 60 as L060 and on photograph 61

as L305. The target should be plotted as shown in figure 31-15.

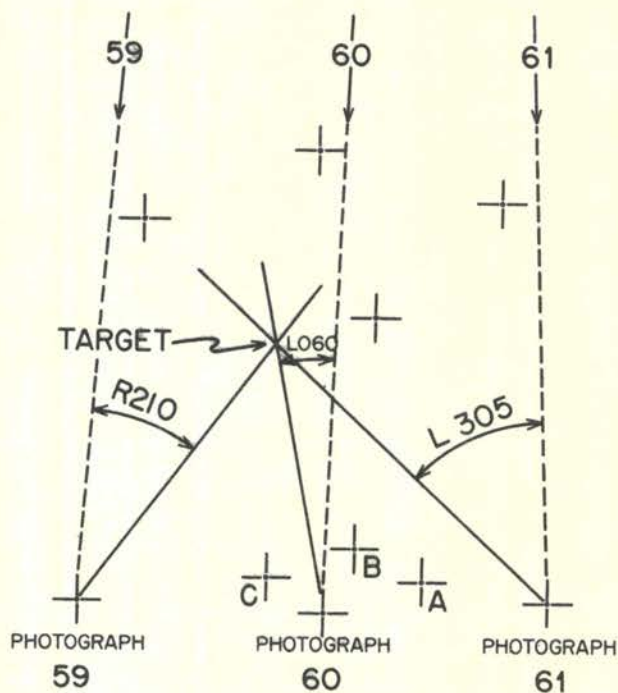


Figure 31-15. Location of a target on the firing chart

31-22. Determination of Altitudes

When mil-gridded oblique photographs are used in conjunction with maps having suitable vertical control, map altitudes are used. If maps are not available, the altitude of the camera is computed and then the vertical interval between the camera and the target is subtracted from the altitude of the camera.

a. Altitude of the Camera. To determine the altitude of the camera, it is necessary to have one point, the chart location and altitude of which are known, identified on the photograph. The vertical interval between the selected point and the camera is determined by using the mil relation. The interval plus the known altitude of the point is the altitude of the camera. For example, a house, the altitude of which has been established by survey, appears at a vertical angle of 100 mils on photograph 59. The distance of the house on the firing chart from the plumb point of photograph 59 is 3,500 meters. Figure 31-16 shows the relations that exist.

Vertical Interval ($3.5 \times$	
(+100))	= +350 meters.
Altitude of house (survey)	= 300 meters.
Altitude of camera (350	
+300)	= 650 meters.

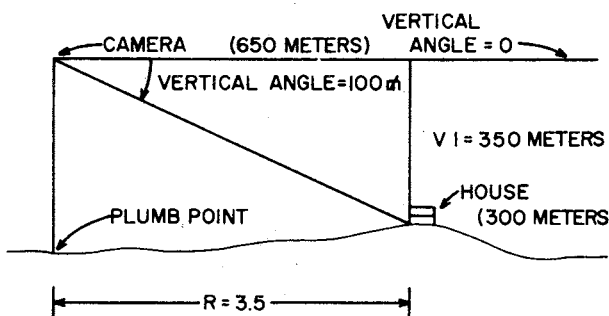


Figure 31-16. Determination of the altitude of the camera

b. Altitude of the Target. The altitude of a target cannot be determined from a mil-gridded oblique photograph until the altitude of the camera has been determined. When this altitude has been established, the altitude of any target can be determined by subtracting the vertical interval between the target and the camera from the altitude of the camera. For example, a target is reported by reference to an oblique photograph as PHOTO 59 R210118. The chart distance, after plotting, from the plumb point is 3,200 meters.

Altitude of camera (a above)	= 650 meters
Vertical interval ($3.2 \times$	
(-118))	= 378 meters
Altitude of target (650 - 378)	= 272 meters

CHAPTER 32

NAVAL GUNFIRE SUPPORT

Section I. INTRODUCTION

32-1. General

Naval gunfire (NGF) and close air support are employed in an amphibious operation prior to the landing of artillery units and for reinforcing artillery in coastal operations. When naval gunfire is used for support of land forces, the Navy is responsible for control and command. Naval gunfire should be requested only when targets cannot be engaged adequately by the artillery and to supplement artillery fires.

32-2. Characteristics of Naval Gunfire Weapons

Naval gunfire weapon characteristics are shown in table 32-1.

32-3. Communication Procedure

Normal artillery communication procedure is used in requesting naval gunfire.

Section II. CALL FOR FIRE

32-4. General

Normally, the call for fire for NGF support will follow the same format as that for artillery support. However, in the first call for fire to a particular ship, the observer will specify the unit of measure to be used (i.e., meters or yards).

32-5. Elements and Sequence of Call for Fire

The following elements are transmitted in the sequence indicated.

a. Observer identification—Same as that for artillery fires.

b. Warning order—Same as that for artillery fires.

c. Location of target—Same as that for artillery fires except the observer may shift to a new target from the target being fired on provided the new target is within 1,000 meters of the target from which the shift is made and END OF MISSION has not been given. To shift to a new target, the observer precedes his call for fire with FRESH TARGET. The command FRESH TARGET insures that the information gained from previous adjustments is not lost and normally bracketing may not be necessary.

d. Description of target—Same as that for artillery fires.

e. Method of engagement—Same as that for artillery fires with the following exceptions:

- (1) *Trajectory*. High- and low-angle fire do not apply to naval gunfire. The observer may request the charge to be used (e.g., full charge or reduced charge).
- (2) *Ammunition*. Ammunition for naval gunfire is similar to standard ammunition for artillery; however, the terminology is different. Shell, high capacity or antiaircraft cannon, fuze quick will be used, as appropriate, if the type of projectile and/or fuze action are not specified by the observer.
- (3) *Distribution of fire*. Distribution of fire is not given by the observer for naval gunfire.

f. Method of fire and control—Same as that for artillery fires with the following exceptions:

- (1) *Method of fire*.
 - (a) Salvo fire is used for all missions. Because the ship is moving, it cannot fire battery right/left.

(b) Normally, the observer requests the number of guns for use during adjustment and the armament to be used. Normally, fire is opened with two or more guns.

(2) *Control.* When the observer wants the ship to adjust the fire, he will identify the target and specify the effect desired and, as the final element of the call for fire, state SHIP ADJUST FIRE.

Table 32-1. Characteristics of Naval Gunfire Weapons

Ship	Class	Armament*	Rate of fire (rounds/min)	Type of ammunition	Type of fuzes	Maximum effective range (yards)
Heavy cruiser (CA).	Baltimore-----	9-8"/55-----	3-4-----	HC, AP, illum, WP-	Q, D, ti-----	26,000
		12-5"/38-----	15-----	HC, illum, WP-----	Q, D, ti, VT---	15,000
	Salem-----	9-8"/55-----	10-----	HC, AP, illum, WP-	Q, D, ti-----	26,000
		12-5"/38-----	12-15----	HC, illum, WP-----	Q, D, ti, VT---	15,000
Guided missile heavy cruiser (CAC).		6-8"/55-----	3-4-----	HC, AP, illum, WP-	Q, D, ti-----	26,000
		10-5"/38-----	15-----	HC, illum, WP-----	Q, D, ti, VT---	15,000
		2-S-A**				
		Missile Launchers.				
Light cruiser (CL)-		12-6"/47-----	4-----	HC, AP, illum, WP-	Q, D, ti, VT---	21,000
		12-5"/38-----	15-----	HC, illum, WP-----	Q, D, ti, VT---	15,000
Guided Missile light cruiser (CLG).		3 to 6-6"/47--	4-----	HC, AP, illum, WP-	Q, D, ti, VT---	21,000
		2 to 6-5"/38--	15-----	HC, illum, WP-----	Q, D, ti, VT---	15,000
Destroyer (DD)---	Sumner-----	6-5"/38-----	15-----	HC, illum, WP-----	Q, D, ti, VT---	15,000
	Sherman-----	3-5"/38-----	40-----	HC, illum, WP-----	Q, D, ti, VT---	22,500
Rocket ships-----	Landing ship med rocket (LSMR).	10-5" S-S*** Rkt launch- ers.	30/barrel-	HC, illum, WP-----	-----	5-10,000
	Inshore fire support ship.	8-5" S-S*** Rkt launch- ers.	35-----	HC-----	Q, D, VT-----	5-10,000

*Number of tubes—diameter of bore/number of calibers.

**Surface to air.

***Surface to surface.

Section III. ADJUSTMENT PROCEDURE

32-6. General

The procedures used in the adjustment of naval gunfire are essentially the same as those used in field artillery fire. All terms used in field artillery adjustment are also used in the adjustment of naval gunfire.

32-7. Terms

Terms used in the adjustment of naval gunfire that are uncommon to the field artillery observer are given in *a* through *h* below.

a. Delay—The term used to indicate that the ship is not ready to fire. The term "delay" is followed by an estimated time to be ready.

b. Straddle—The term sent when multigun fires straddle the target.

c. Large spread—The term used to indicate that the distance between bursts is excessive.

d. Trend—The term sent if fires are observed to

be creeping off the target and is followed by an indication of direction; for example, TREND SOUTHWEST.

e. Fresh target—The term used when a new target appears within 1,000 meters from the target being fired on and end of mission is not desired. This reduces confusion caused by a large shift.

f. Neglect—The term used to inform the observer that the last rounds were fired with incorrect settings.

g. Will not fire—The term used to indicate, for safety or other reasons, that the ship is unable to fire; for example, the ship is under attack.

h. Salvo fire—The term used to describe the method of fire in which a number of weapons are fired at the same target simultaneously.

i. Danger—The term used to indicate that friendly forces are within 600-1500 meters of the target.

CHAPTER 33

ARMOR EMPLOYED IN A FIELD ARTILLERY MISSION

33-1. General

a. Tank guns normally are not used in the field artillery (indirect fire) role because of the high velocity, flat trajectory and short tube life of tank guns and the small bursting radius of the ammunition. However, under exceptional circumstances, a command decision may be made to employ tanks in an indirect fire role under the operational control of the supporting field artillery. The tank unit may either be attached or given a reinforcing mission. The field artillery unit is responsible for fire control, communication, and survey; and, if the tank unit is attached, it is also responsible for ammunition, fuel, rations, and other supplies. Whether attached or reinforcing, the tank unit must retain the capability of immediately reverting to its primary role.

b. This chapter deals with the gunnery techniques used when the tank unit is under the control of the field artillery. For information on the mission and the tactical employment of tank units, on the characteristics of the tank and fire control material, and on direct fire with tank weapons, see the FM 17-series.

33-2. Ammunition

a. HE and WP projectiles are available for all tank guns.

b. A typical basic load will include approximately 60 percent HE, 15 percent WP, and 25 percent antitank ammunition.

c. HE and WP projectiles are issued with combination superquick and delay fuzes. Combination mechanical time and superquick or concrete-piercing fuzes may be obtained and substituted for the normal fuzes if required.

Note. See TM 9-1300-203 and table 1-2 for further information on ammunition.

33-3. Observer Procedure

Field artillery observer procedures as covered in part three are used in conducting indirect fire with tanks.

33-4. Fire Direction

a. Firing Chart. The location of each tank platoon is plotted on the field artillery firing chart, and the range-deflection protractor is numbered in the same way as for field artillery. The deflection index is placed at deflection 3200. If tank weapon firing tables are not available to the fire direction center, the tank unit normally fires only observed fire in the indirect role. If tabular or graphical firing tables are available, a registration should be conducted and the deflection index and deflection correction scale should be set up by using the procedures described in chapter 20. Corrections sent by the observer during adjustment are plotted by using the target grid as described in chapter 16.

b. Fire Commands. Fire commands are sent from the fire direction center to the tank unit fire control officer, who is responsible for tank fire. The elements and sequence of fire commands differ slightly from those for field artillery. An example of the sequence is shown in the following fire commands:

PLATOON
HE
12,000, up 10
FROM REFERENCE POINT, RIGHT 115
MORTARS FIRING
FIRE

(1) *Platoon.* The normal method of employing tanks in an indirect fire role is by platoon (five tank guns). To alert (pieces to follow) all five weapons, the command is PLATOON.

(2) *HE.* The ammunition command is similar to that for field artillery except that the word "shell" is omitted and the fuze is also part of the command; e.g., HE DELAY. If fuze quick is desired, only the shell command is given; e.g., HE. When firing fixed ammunition, no charge command is given.

- (3) *12,000, up 10.* The range command (12,000) is given to the nearest 100 meters. The elevation to be fired is determined at the tank position. When the target is at a different altitude from that of the tank, an angle of site is computed in mils and included as part of the command (UP 10). The complementary angle of site for high-velocity guns is negligible and is ignored. If the artillery fire direction center has tabular or graphical firing tables, an elevation is normally computed instead of range. The command QUADRANT, which includes the angle of site, is sent to the tanks; i.e., QUADRANT 430. The tank weapons may be laid for elevation by using either the gunner's quadrant or the elevation quadrant. Since the range of most tank weapons is limited by the inability of the tanks to elevate to high angles, it may be necessary either to dig in the rear of the tanks or to place the tanks on a ramp which slopes away from the direction of fire.
 - (4) *From reference point, right 115.* The direction command is given in terms of a reference point. In the indirect fire role, the tanks are laid on an azimuth, and this azimuth is considered the reference point. When the tank is laid, the azimuth indicator is zeroed. Changes in direction are given as right or left of the reference point (azimuth on which laid). Aiming posts may be set out and aligned on a common deflection, usually 2,600 or 2,800 mils (this is to right front). Since the tank does not have a panoramic sight, the aiming post deflection is merely an offset angle out of the line of fire. During lulls in firing, the gunner checks tank displacement by using the aiming posts without turning the turret (tube) back to the aiming circle. Since tank units normally zero the gunner's aid between direction changes, the fire direction center personnel must send the difference in deflection to the tank. For example, a tank platoon is laid on azimuth 1600, and a deflection index has been placed on the chart at deflection 3200. The chart deflection to an announced target is 3,085 mils (azimuth 1715). The direction command to the tank is FROM REFERENCE POINT, RIGHT 115. The turret (tube) is turned 115 mils to the right, and the gunner's aid is zeroed. The chart deflection to the target plot after the observer correction is 3,093 mils (azimuth 1707). The direction command is LEFT 8. An alternate method of direction control, which has the advantage of minimizing directional errors by the nonadjusting tanks, is to give all direction commands as deflections in the same manner as that used for artillery weapons. Although the azimuth indicator must be zeroed after the tank is laid, the gunner's aid is not moved or zeroed between rounds. The turret (tube) is moved until the reading on the azimuth indicator is the commanded deflection. In the above example, the initial direction command is DEFLECTION 3085. The gunner moves the turret until 3085 is read on the azimuth indicator (fig. 33-1). The gunner's aid is not zeroed. The next direction command is DEFLECTION 3093. The turret is moved until 3093 is read on the azimuth indicator (fig. 33-2).
 - (5) *Mortars firing.* The nature of the target is announced to the tank unit as a portion of the fire command.
 - (6) *Fire.* The command to open fire is FIRE. In tank gunnery, this command is the last element in the sequence of fire commands, because the tank gunner is trained to hold his fire until the command FIRE is received.
- c. Other Fire Commands.* Other fire commands used by the artillery and not mentioned in *b* above, which at times would logically apply to the tank unit (e.g., pieces to fire, method of fire), are sent to the tanks in the simplest and most understandable manner. Commonsense and liaison between artillery and armor should overcome difficulties caused by lack of formal procedure. This problem is further alleviated through the use of pre-arranged data sheets.
- d. Distribution.* The normal width of a tank platoon front in the position area is about 150 meters. If tanks are armed with 90-mm guns, a

parallel sheaf produces an effective pattern of bursts with this position-area width. For tanks armed with guns of other calibers and for position areas of different widths, it is necessary to adjust the width of sheaf in order to obtain the most effective pattern of bursts.

33-5. Alternate Methods

Other methods, which may be employed to control the indirect fire of tanks are as follows:

a. Independent Method. The tank unit uses fire direction equipment and personnel organic to the tank battalion to form, with artillery assistance, a fire direction center.

b. Semi-Independent Method. The tank unit handles its own indirect fire missions from prearranged data sheets. Survey control, meteorological computations, prearranged data sheets, and assistance in laying the tanks may be provided by the supported artillery. Interdiction and harassing missions are the types most effectively handled by use of data sheets.

33-6. Survey

The survey necessary for the indirect firing of the tanks, such as the establishment of their position area locations, is made by the field artillery battalion before the arrival of the tanks or as soon after their arrival as possible.

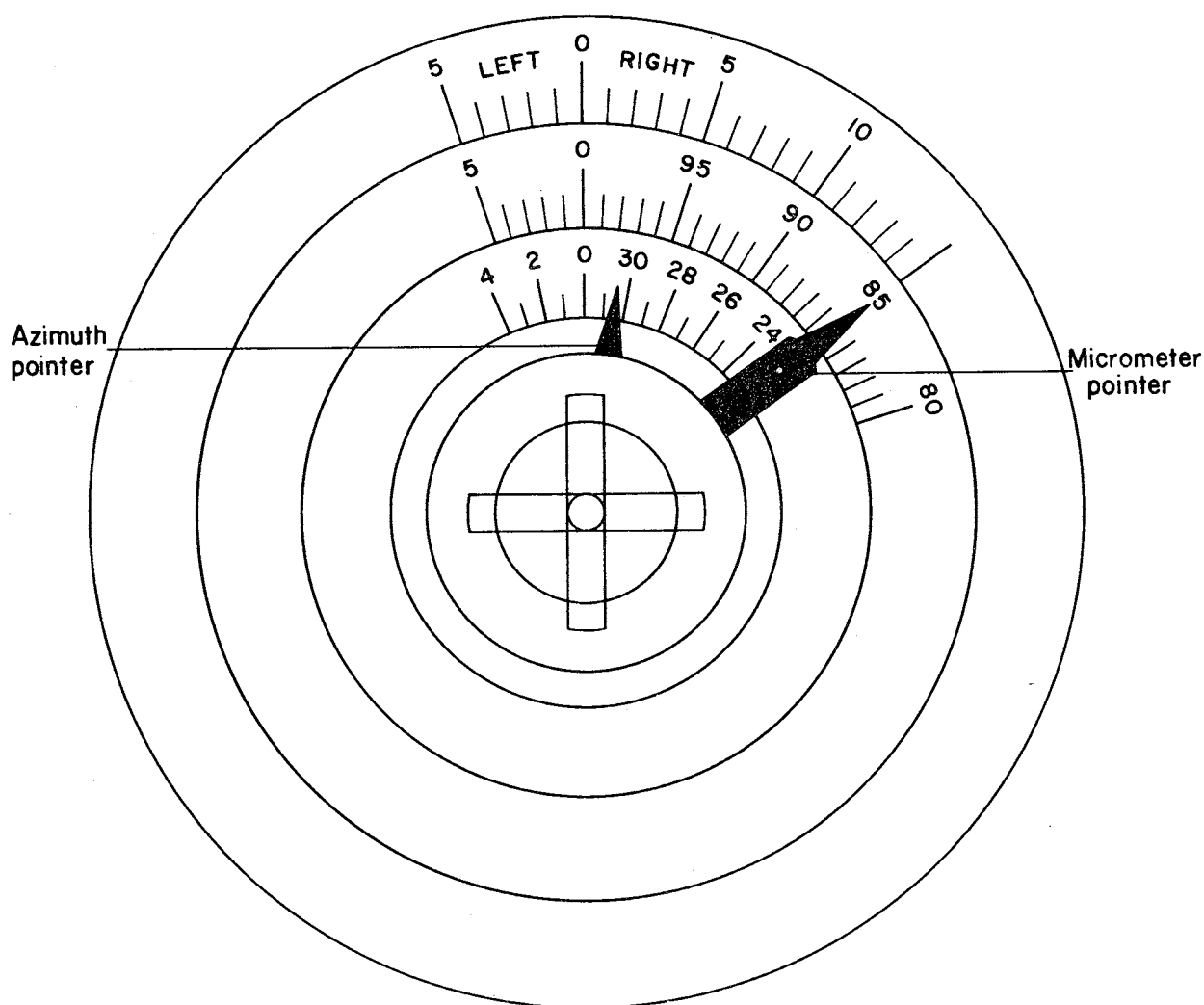


Figure 33-1. Deflection 3085 on azimuth indicator

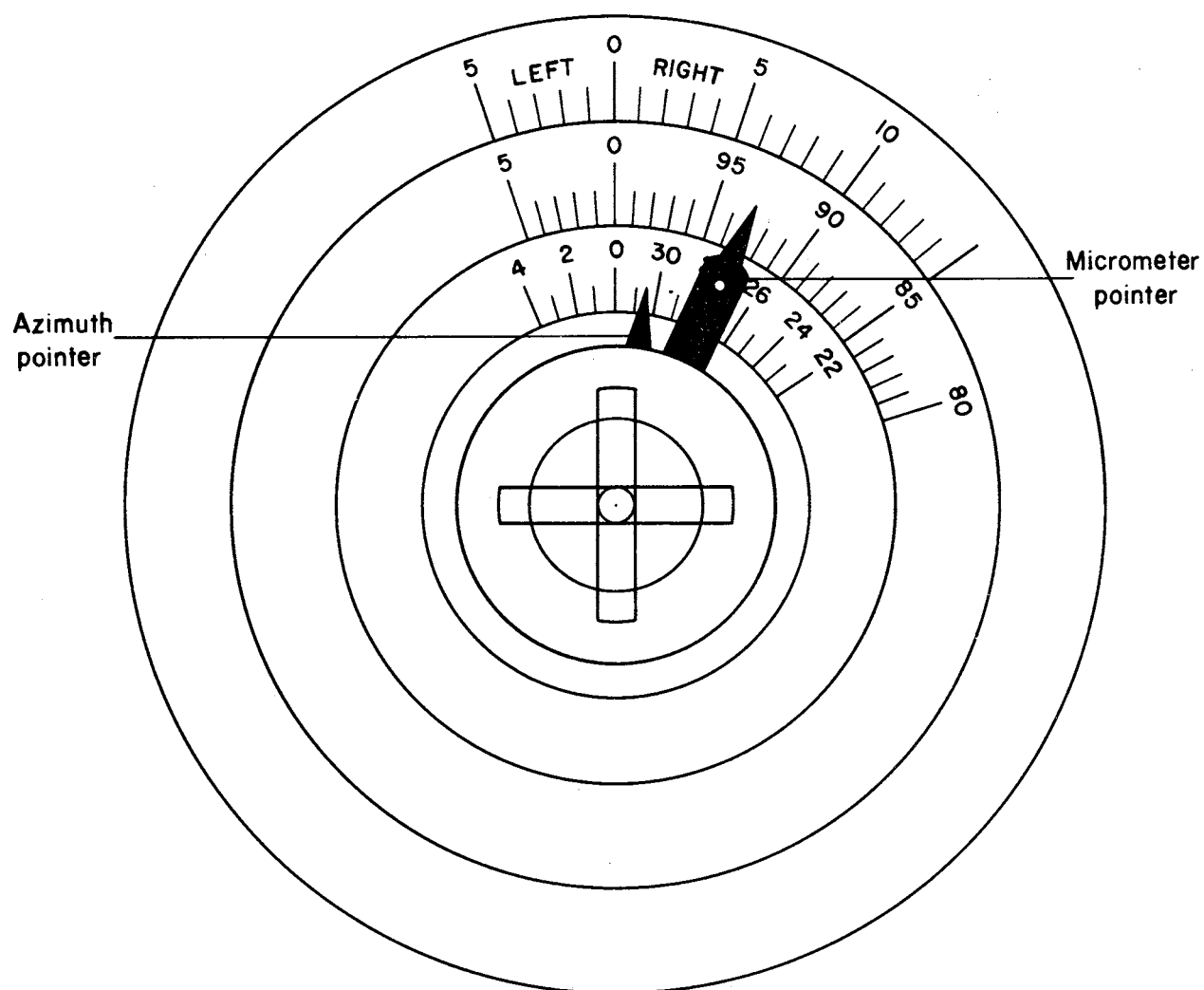


Figure 33-2. Deflection 3093 on azimuth indicator

APPENDIX A

REFERENCES

A-1. Publications Indexes

Department of the Army Pamphlets of the 310-series should be consulted frequently for latest changes or revisions of references given in this appendix and for new publications relating to material covered in this manual.

A-2. Army Regulations

310-25	Dictionary of United States Army Terms
310-50	Authorized Abbreviations and Brevity Codes
385-63	Regulations for Firing Ammunition for Training, Target Practice, and Combat
★75-1	Malfunctions Involving Ammunition and Explosives

A-3. Department of Army Pamphlets

108-1	Index of Army Motion Pictures and Related Audio-Visual Aids.
310-series	Index of Military Publications

A-4. Field Manuals

3-10	Employment of Chemical and Biological Agents
6-2	Field Artillery Survey
6-3-1	Operation of the Gun Direction Computer — M18 Cannon Application
6-20-1	Field Artillery Tactics
6-20-2	Field Artillery Techniques
6-70	105-mm Howitzer, Light, M102 Towed
6-75	105-mm Howitzer M101 Series, Towed
6-77	105-mm Howitzer M52, Self-Propelled
6-79	105-mm Howitzer M108, Self-Propelled
6-81	155-mm Howitzer M114, Towed
6-88	155-mm Howitzer M109, Self-Propelled
6-90	8-inch Howitzer M2, Towed
6-92	155-mm Howitzer M44 Self-Propelled
6-94	175-mm Gun M107, Self-Propelled, and 8-inch Howitzer M110, Self-Propelled
6-115	The Field Artillery Searchlight Battery
6-120	The Field Artillery Target Acquisition Battalion and Batteries
6-122	Artillery Sound Ranging and Flash Ranging
6-125	Qualification Tests for Specialists, Field Artillery
6-140	Field Artillery Cannon Battalions and Batteries
6-160	Counter battery Radar Set AN/MPQ-10A
6-161	Radar Set AN/MPQ-4A
11-40	Signal Corps Pictorial Operations
17-12	Tank Gunnery
21-5	Military Training Management
21-6	Techniques of Military Instruction
21-26	Map Reading
21-30	Military Symbols
23-92	4.2-inch Mortar M30
100-5	Operations of Army Forces in the field.

C 2, FM 6-40

A-5. Technical Manuals

5-230	General Drafting
6-230	Logarithmic and Mathematical Tables
6-240	Slide Rule, Military, Field Artillery
9-325	Operator and Organizational Maintenance Manual: Howitzer, Light, Towed, 105-mm M101 and M101A1
9-1015-215-12	Operator and Organizational Maintenance Manual: Mortar 4.2-Inch: Cannon M30 on Mount M24 or M24A1; and Mortar, Sub-caliber, 60-mm: M31
9-1015-234-12	Operator and Organizational Maintenance Manual: (Including Repair Parts and Special Tools Lists) Howitzer, Light, Towed: 105-mm, M102
9-1025-200-12	Operator and Organizational Maintenance Manual: Howitzer Medium Towed: 155-mm M114 and M114A1; and Howitzer, Medium, Towed, Auxiliary Propelled, 155-mm, M123A1
9-1300-200	Ammunition, General
9-1300-203	Artillery Ammunition
9-2300-216-10	Operator's Manual, Gun, FA, SP, 175-mm, M107 (2350-436-6635) and Howitzer, Heavy, SP, 8-Inch, M110 (2350-439-6243)
9-2300-216-20	Organizational Maintenance Manual, Gun, FA, SP, 175-mm, M107 (2350-436-6635) and Howitzer, Heavy, SP, 8-Inch, M110 (2350-439-6243)
9-2350-217-10	Operator's Manual, Howitzer, Light, SP, 105-mm, M108 (2350-440-8810) and Howitzer, Medium, SP, 155-mm, M109 (2350-440-8811)
9-2350-217-20	Organizational Maintenance Manual, Howitzer, Light, SP, 105-mm, M108 (2350-440-8810) and Howitzer, Medium, SP 155-mm, M109 (2350-440-8811)
11-287	Radio Sets AN/VRQ-1, AN/VRQ-2, and AN/VRQ-3
30-245	Image Interpretation Handbook
38-750	The Army Maintenance Management System

★ A-6. Firing Tables

4.2-F-1	Mortar, 4.2-Inch, M430; firing projectiles, HE, M329 and M329B1; projectile, HE, M3A1; projectile, HE, M3 and M3 alternate; projectile, chemical, M2A1 (WP, FS, HD); projectile, chemical M2 and M2 alternate (WP, FS, FM, H, HT, HD, CG); projectile, chemical, E84R7 (WP) (M328); projectile, illuminating, M335 (E71R1).
8-J-4	Cannon, 8-Inch howitzer: M2 and M2A1 on howitzer, heavy, towed: 8-Inch, M115 cannon, 8-Inch howitzer: M47 on howitzer, heavy, self-propelled, full-tracked: 8-Inch, M55 cannon, 8-Inch howitzer: M2A1E1 on howitzer, heavy, self-propelled: 8-Inch, M110 firing projectile, HE, M106, projectile, chemical, M426.
8-0-4	Cannon, 8-Inch howitzer: M2 and M2A1 on howitzer, heavy, towed: 8-inch, M115, cannon, 8-inch howitzer: M2A1E1 on howitzer, heavy, self-propelled: 8-inch, M110 cannon, 8-inch howitzer: M47 on howitzer, heavy, self-propelled, full-tracked: 8-inch, M55; firing projectile HES, M424, projectile, atomic, M422.
105-H-6	Cannon, 105-mm howitzer, M2A2 and M2A1 on howitzer, light, towed, 105-mm, M101A1 and M101 and cannon, 105-mm howitzer, M49 on howitzer, light, self-propelled, full-tracked, 105-mm, M52A1 and M52; firing cartridge, HE, M1; cartridge, gas, persistent, H, M60; cartridge, gas, persistent, HD, M60; cartridge, gas, nonpersistent, GB, M360; cartridge, smoke, WP, M60; cartridge, smoke, BE, M84 and M84B1 (HC and colored); cartridge, illumin-

	ating, M314A2E1; cartridge, HEP-T, M327.
105-ADD-B-2	Firing table addendum to FT 105-H-6 for cartridge, HE, M444.
155-ADD-A-1	Firing table addendum to FT 155-Q-3 for projectile, HE, M449 (T379E2).
155-ADD-B-1	Firing table addendum to FT 155-AH-2 for projectile, HE, M449A1 (M449E2).
155-AH-2	Cannon, 155-mm howitzer, M126E1 and M126 on howitzer, medium, self-propelled: 155-mm, M109, firing projectile, HE, M107; projectile, smoke, WP, M110; projectile, smoke, BE, M116 and M116B1 (HC and colored); projectile, gas, persistent, HD, M110; projectile, gas, persistent, H, M110; projectile, gas, nonpersistent, GB, M121A1; projectile, gas persistent, VX, M121A1; projectile, illuminating, M118, M118A1, M118A1B1, M118A2 and M118A2B1; projectile, illuminating, M485E2, M485E1 and M485.
155-AJ-2	Firing tables for cannon, 155-mm howitzer, M126E1 and M126 on howitzer, medium, self-propelled, 155-mm, M109 firing projectile, atomic, XM454.
155-Q-4	Howitzer, medium, towed, 155-mm, M114A1 and M114; howitzer, medium, self-propelled, full-tracked, 155-mm, M44A1 and M44; howitzer, medium, towed, auxiliary propelled, 155-mm, M123A1; firing projectile, HE, M107; projectile, smoke, WP, M110; projectile, smoke, BE, M116 and M116B1 (HC and colored); projectile, gas, persistent, HD, M110; projectile, gas, persistent, H, M110, projectile, gas, non-persistent, GB, M121A1; projectiles, gas, persistent, VX, M121A1; projectile, illuminating, M485E2, M485E1 and M485.
175-A-1	Cannon, 175-mm gun: M113, M113E1 on gun, Field Artillery, self-propelled: 175-mm, M107 firing projectile, HE, M437A2, M437A1.

A-7. DA Forms (Available through normal AG publications supply channels.)

6-12	Record of Precision Fire
6-13	Firing Battery Section Data Sheet
6-14	Firing Battery Data Sheet
6-15	Met Data Correction Sheet
3622	FDC Computer's Record
3623	Firing Battery Recorder's Sheet
6-53	Target Grid, Scale 1:25,000 Meters
6-55	High-Burst (Mean Point of Impact) Registration Computation of HB (MPI) Location
2408-4	Weapon Record Data

A-8. Joint Army Navy Air Force Procedure

164	Joint Radio and Telephone Procedure for Conduct of Artillery and Naval Gunfire
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By Order of the Secretary of the Army:

HAROLD K. JOHNSON,
General, United States Army,
Chief of Staff.

Official:

KENNETH G. WICKHAM,
Major General, United States Army,
The Adjutant General.

Distribution:

To be distributed in accordance with DA Form 12-11 requirements for FA Cannon Gunnery.

Tank Weapons Used in the Field Artillery Role

Weapon	Weight	Time to Emplace (min)	Elevation		Traverse	Range (meters)	Rate of fire--Max (rd/min)
			Min	Max			
Tank, 76-mm gun, M41 (series)	51,000	1	-73	+355	6,400	14,320	8
Tank, 90-mm gun, M48A2	104,000	1	0	+338	6,400	18,150	8
Tank, 105-mm gun, M60A1	106,000	1	0	+356	6,400	18,205	6
Tank, 120-mm gun, M103A1	125,000	1	-142	+267	6,400	18,200	4

Table 1-2. Ammunition Chart
(Older fuzes authorized for use are listed in TM 9-1300-203.)

Weapon	Designation	Type	Filler composition	Weight of projectile as fired (pounds)	Weight of complete RD (max charge)	How shipped	Fuzes				References	Remarks
							Point detonating	Base detonating	Mech time Superquick	Proximity (VT)		
75-mm howitzer	Cartridge, M48	HE	TNT	14.7	18.2	Fuzed	M557 M78 (series)		M564 (series)	M513 (series)	TM 9-1300-203 TM 9-319 FT 75-I-4	Issued fuzed with PD fuze. SM 9-5-1315
90-mm gun M47 and M48	Cartridge, M71A1	HE	Comp B	23.4	42.4	Fuzed	M535 M557		M520 (series)	M513 (series)	TM 9-1300-203 TM 9-2300-200-12 TM 9-7022 SM 9-5-1315	See TM 9-1300-203 for fuzes used in the antitank role.
	Cartridge, M313C	Smoke	WP	23.6	40.1	Fuzed	M48A3 M557					
105-mm gun M60	Cartridge, M393-A1	HEP-T	Comp A3	24.1		Fuzed		M534			TM 9-1300-203 TM 9-2350-210-10 SM 9-5-1315	Complete weight not available.
105-mm howitzer (all)	Cartridge, M1	HE	Comp B	33.0	42.0	Fuzed	M557 M78A1		M564 (series)	M513 (series)	TM 9-1300-203 TM 9-325 TM 9-7204 TM 9-2350-217-10 SM 9-5-1315 FT 105-H-6 FT 105-AS-1 FT 105-ADD-B-1 FT 105-ADD-D-0 (Rev II) FT 105-ADD-E-0 (Rev II)	Ammunition issued for training may be issued fuzed or unfuzed. When issued, fuzed (HE) will be issued with PD fuze. M508 PD fuze can also be used.
	Cartridge, M314 (series)	Illuminating	Illuminating	34.9	43.9	Fuzed			M501(series) M565(series)			
	Cartridge, M60	Gas	H or HD	33.9	42.9	Fuzed	M557					
	Cartridge, M360	Gas	GB	35.4	44.4	Fuzed	M557 M508					
	Cartridge, M84 (series)	Smoke, HC, and colored BE	HC	32.9	41.9	Fuzed			M501 (series)			
	Red	30.7	39.7									
	Yellow	30.3	39.3									
	Green	31.1	39.1									
	Cartridge, M60	Smoke	WP	34.8	43.8	Fuzed	M557					
	Cartridge, M67	HEAT, HEAT-T	Comp B	29.3	37.1	Fuzed		M62A1 M91A1				
	Cartridge, M327	HEP, HEP-T	Comp A3	23.4	33.4	Fuzed		M62 M91				
	Cartridge, XM546	Anti-personnel	Flechettes	28.5	38.2	Fuzed			XM563(series) MAMT		Fuze comes set for muzzle action and can be set for mechanical time action.	
120-mm gun M103A1	Projectile, M73	HE	TNT	50.0	99.7	Fuzed	M507		M506		TM 9-1300-203 TM 9-2350-214-10 SM 9-5-1315	Also can use M535 and M78 (series) fuzes. Also can use M508 and M535 PD fuzes.
	Projectile, M356	HE-T	Comp B	50.4	88.7	Fuzed	M557		M564(series) M520(series)			
	Projectile, M357	Smoke	WP-T	50.4	88.7	Fuzed	M557					
155-mm gun M53	Projectile, M101	HE	TNT	95.0	126.6	Unfuzed	M557		M564(series) M520(series)	M514 (series)	TM 9-1300-203 TM 9-350 TM 9-2300-250-12 SM 9-5-1320 FT 155-Q-2	
	Projectile, M104	Smoke or gas HD	Smoke	98.2	129.8	Unfuzed	M557					
			HD	92.7	124.3	Unfuzed	M535, M508					
155-mm howitzer (all)	* Projectile, M107	HE	TNT	95.0	108.6	Unfuzed	M557		M564 M520(series)	M514 (series)	TM 9-1300-203 TM 9-331B TM 9-7004 TM 9-2350-217-10 SM 9-5-1320 TM 9-1025-200-12 FT 155-Q-3 FT 155-AH-2 FT 155-AI FT 155-AJ-1 FT 155-ADD-A-1	*Also authorized for use with 155-mm gun using normal charge only. M508 and M535 PD fuzes may also be used.
	* Projectile, M110	Gas	H or HD	98.5	112.1	Unfuzed	M557					
	* Projectile, M121A1	Gas	GB or VX	101.8	115.4	Unfuzed	M508			M514 (series)		
	* Projectile, M110	Smoke	WP	97.5	115.2	Unfuzed	M557					
	* Projectile, M116(series)	Smoke, HC, and colored BE	HC	94.4	108.0	Unfuzed				M501 (series)		
			Red	86.4	100.0							
			Yellow	86.4	100.0							
			Green	86.4	100.0							
	* Projectile, M485	Illuminating	Illuminating	91.4	103.6	Unfuzed			M565(series)			
	* Projectile, M118(series)	Illuminating	Illuminating	100.0	113.6	Unfuzed			M501 (series)			
Projectile, XM454	Atomic		120.0	138.0	Unfuzed			XM32E1	T361E2			
175-mm gun M107	Projectile, M437A1	HE	TNT	147.0	202.0	Unfuzed	M572		M514A1*	M514 (series)	TM 9-1300-203 TM 9-2300-216-10 FT 175-A-0 (Rev II)	*Designated selected lots to be used for charge 3 firings.
	Projectile, M437A2	HE	Comp B	148.0	203.0	Unfuzed	M572		M514A1*			
8-in howitzer (all)	Projectile, M106	HE	TNT	200.0	228.3	Unfuzed	M557		M564 M520(series)	M514 (series)	TM 9-1300-203 TM 9-3004 TM 9-2300-250-12 TM 9-2300-216-10 TM 9-5-1320 FT 8-J-3 FT 8-0-3 FT 8-ADD-A-0	
	Projectile, M424	HE Spotting	Tritonal	242.0	272.0	Unfuzed			M543 (MT only)			
	Projectile, M422	Atomic		242.0	272.0	Unfuzed			M542			
	Projectile, M426	Gas	Gas GB, or VX	200.0	228.3	Unfuzed	M508			M514 (series)		

Table 27-2. Typical Targets and Suggested Methods of Attack

Type of target	Type of adjustment	Weapon	Projectile	Fuze	Type of fire	Remarks (see footnotes)
Group I						
Armored vehicles (rendezvous).	Observed, unobserved.	All (pref 155-mm or larger).	HE, HEAT.	VT, ti, Q.	Neutralization, destruction, assault.	(1), (2), (3).
Armored vehicles (moving).	Observed.	All (pref 155-mm or larger).	HE, WP, HEAT.	VT, ti, Q.	Neutralization, destruction, assault.	Projectile HE to force tanks to "button up." Fire of sufficient intensity may demoralize and break up attack. WP may blind vehicle drivers, but it may also obscure adjustment. (2).
Vehicles (rendezvous).	Observed, unobserved.	All.	HE, WP.	Q, VT, ti.	Neutralization, destruction.	(1), (2), (4).
Vehicles (moving).	Observed.	All.	HE, WP.	Q, VT, ti.	Neutralization, destruction.	(2), (4), (6).
Weapons (fortified).	Observed.	All (pref 155-mm or larger).	HE.	Q, CP, delay.	Destruction, neutralization.	Airbursts are desirable if weapon is firing. After weapon is silenced, it is attacked for destruction. Choice of fuze is determined by type of fortification. See fortifications.
Weapons (in open).	Observed, unobserved.	All.	HE, WP.	VT, ti.	Neutralization, destruction.	(1), (2), (4).
Group II						
Boats.	Observed.	All.	HE.	VT, ti.	Neutralization, direct.	Airbursts against personnel manning boats. Destruction by direct fire.
Bridges.	Observed, unobserved.	All (pref 155-mm or larger).	HE.	Q, CP, delay.	Destruction, harassing, interdiction.	Direction of fire preferably with long axis of bridge. Destruction of permanent bridges is accomplished best by knocking out bridge support. Fuze quick for wooden or pontoon bridges.
Buildings (frame).	Observed, unobserved.	All.	HE, WP.	Q.	Neutralization.	(4).
Buildings (masonry).	Observed, unobserved.	All (pref 155-mm or larger).	HE.	CP, delay, Q.	Destruction, neutralization of large areas.	Several weapons can be converged on one building. In destroying masonry buildings, the fact that rubble aids defensive fighting and delays friendly mobile elements must be considered (5).
Fortifications (armor).	Observed.	All.	HEAT, HE (large calibers).	Q.	Destruction, assault, direct.	Fire should be adjusted at apertures of steel turrets and pillboxes. (5). Use highest practicable charge.
Fortifications (concrete).	Observed.	All (pref 155-mm or larger).	HE.	CP, delay, Q.	Destruction, assault, direct.	Use highest practical charge. (5).
Fortifications (earth, logs, etc).	Observed.	All (pref 155-mm or larger).	HE.	Delay, Q.	Destruction, assault, direct.	Use highest practical charge. (5).
Personnel (in open).	Observed, unobserved.	All.	HE.	VT, ti, Q.	Neutralization, harassing.	TOT missions are most effective. Fuze quick should be fired at lowest practical charge (steep angle of fall gives better fragmentation). Intermittent fire is better than continuous fire. (1).
Personnel (dug in).	Observed.	All.	HE, WP.	VT, ti, delay (ricochet).	Neutralization, harassing, destruction.	Airbursts are necessary. Surprise not necessary. WP is useful in driving personnel out of holes and into open.
Personnel (in dugouts or caves).	Observed.	All (pref 155-mm or larger).	HE.	Delay, Q.	Destruction, assault, direct.	(5).
Personnel (under light cover).	Observed, unobserved.	All.	HE.	Q, VT, ti, delay (ricochet).	Neutralization.	(4).
Roads and railroads.	Observed.	All (pref 155-mm or larger).	HE.	Delay, CP.	Destruction.	Attack critical points: defiles, fills, crossings, culverts, bridges, and narrow portions. Direction of fire should coincide with direction of road.
Supply installations.	Unobserved.	All.	HE.	VT, ti, Q.	Harassing, interdiction.	
	Observed, unobserved.	All.	HE, WP.	Q, VT, ti.	Neutralization, destruction.	(1), (4).

(1) Area is neutralized with projectile HE (airbursts if practical). Surprise is essential to produce casualties.

(2) Materiel remaining in area should be attacked for destruction by using appropriate projectile and fuze.

(3) Projectile HEAT may be used in fire for effect provided that ranges and observing distances are short enough to permit sensing rounds.

(4) Projectile WP should be combined with HE when the target contains inflammable material and the smoke will not obscure adjustment.

(5) Projectile HE with fuze quick is fired at intervals to clear away camouflage, earth cover, and rubble.

(6) The first objective in firing on moving vehicles is to stop the movement. For this purpose a deep bracket is established so that the target will not move out of the initial bracket during adjustment. Speed of adjustment is essential. If possible, the column should be stopped at a point where vehicles cannot change their route and where one stalled vehicle will cause others to stop. Vehicles moving on a road can be attacked by adjusting on a point on the road and then timing the rounds fired so that they arrive at that point when a vehicle is passing it. A firing unit or several units, if available, may fire at different points on the road simultaneously.

(7) Other references:

a. (C) FM 6-141-1, Nonnuclear Employment of Field Artillery Weapons Systems (U).

b. (S) FM 6-141-1A, Nonnuclear Employment of Field Artillery Weapons Systems (Biological) (U).

c. Graphical Effects Table, Artillery Weapons (USAAMS).